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INTERAGENCY ECOLOGICAL PROGRAM FOR THE SAN FRANCISCO ESTUARY

IEP NEWSLETTER

Interagency Ecological Program

COOPERATIVE ECOLOGICAL INVESTIGATIONS SINCE 1970

In this Issue:

IEP NEWSLETTER

Interagency Ecological Program for the San Francisco Estuary

Vol. 40 Issue 2, 2021

The Newsletter is a triannual product of the Interagency Ecological Program (IEP) that publishes perspectives on our Program and community, reviews, data reports, research articles, and research notes. The Newsletter is a forum for resource managers, scientists, and the public to learn about recent important programmatic and scientific topics from across the San Francisco Estuary. Articles in the IEP newsletter are intended for rapid communication and are not peer reviewed. Primary research results reported in the Newsletter should, therefore, be considered preliminary and interpreted with caution.

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Article Submission Deadlines for this Calendar Year:

Issue	Article Submission Deadline
1 (Winter)	February 15
2 (Spring)	June 15
3 (Summer/Fall)	October 15

*Above: A flying Batray (*Myliobatis californica*) being released by deckhand Kevin Juranek while Science Aide Rebecca Heisey sorts a Bay Study trawl haul on the RV Longfin. Credit: David Hull (CDFW)*

Cover: The Golden Gate Bridge shrouded in fog from the stern of the RV Longfin as Dave Hull and Harrison Morrow deploy a Bay Study trawl. Credit: Jereme Gaeta (IEP & CDFW)

IEP IN 2021

Implementing Change

Steven Culberson, IEP Lead Scientist
Stephanie Fong, IEP Chair

As we recover from one of the more unusual years in recent memory due to COVID-19 related disruptions to our IEP Annual Workshop, our Annual Planning meetings, and a host of other professional and personal challenges and tragedies, we choose to look forward to implementing needed changes to the Interagency Ecological Program. We suggest for IEP's near future a conscientious focus on updating our important and foundational estuary monitoring science program. We propose a series of thematically oriented survey effort reviews over the next several years with the aim of using historical and updated data and methods to improve what we do on the ground and how we create information for resource managers. We suggest these reviews should be an ongoing and routine task within the IEP Annual Plan. Adding and refining survey reviews and analysis as Program Elements in our Annual Work Plans and being responsive to calls for closing the loop between management action, data collection, analysis, learning, and science communication to managers will improve achievement of Program objectives. Additionally, Science Management Team meetings will be devoting time each month to scanning and discussing publications from the literature that pertain to issues we are having in the San Francisco Bay-Delta, and we will use these discussions to better inform conversations between IEP Directors, Program Managers, and our associated scientists and technical experts.

Additions to monitoring programs to serve the needs of the Delta Smelt and Longfin Smelt Science Plans and CDFW Incidental Take Permit conditions for operations of the Water Projects will receive priority over the next few years, with some aggressive timelines for required changes and improvements. We will have to openly engage at the Science Management Team and Coordinators Team levels to understand needs and opportunities associated with any modification of surveys in these efforts. These teams will regularly discuss and assign needed actions and resource adjustments with the 2021 Annual Work Plan and other Plans into the future. Providing technical and logistical perspective on how survey adjustments affect the fulfillment of survey objectives will be an important task for members of the Science Management Team, and the IEP Lead Scientist will bear responsibility for communicating any impacts clearly and quickly to the IEP Coordinators and Directors.

The rapid adoption of a program to support Delta Smelt aquaculture and wild population supplementation will challenge all IEP agencies and personnel in 2021 and beyond. New Delta smelt culture and handling techniques; detection surveys for young-of-the-year, juvenile, and larval smelts; monitoring in more diverse habitats; and methods for integrating IEP catch data will all need appropriate updating, resource investment, and training to produce useable information and policy-relevant management alternatives. We will all need to improve our communication and efficiencies as the need for our IEP scientific services grows and expands.

IEP efforts to bolster and further emphasize activities within the Synthesis Technical Team to produce useful science communications products across IEP activities are also important priorities as we support the Delta Science Program's Science Action Agenda and the pursuit of our "One Estuary, One Science" paradigm. We will continue to publish IEP data in open formats (specifically, the Environmental Data Initiative) that facilitates greater use of IEP science within and beyond our estuary. The new IEP website and (IEP website) provides all Project Work Teams a venue to describe, share, and announce activities, meetings, and products. It is difficult to track and understand all that IEP surveys and studies, but the IEP Synthesis Team continues to inform and improve communications about pressing management issues to the Coordinators and Directors, and the larger Delta community. We will be highlighting the role of integration and synthesis of collected IEP data in the months and years to come.

Building depth in our program is essential for IEP's long-term success. Cross-training agency staff by job-swapping and rotation of committee assignments and broadening technical abilities via training and technical project participation will help us to support retirements, staff redirections, and other changes to personnel resources. Mentorship will be key to maintaining our technical breeding ground – taking up a responsibility to train those that come after us will enhance the abilities of our newer leaders and benefit the Program by enlarging the larger Bay-Delta science community.

Maintaining a scientifically excellent monitoring program to meet regulatory requirements requires careful, open, and transparent conversations among Program Managers, contract leads, Principal Investigators, scientists, and data users. We view iterative conversations at the Science Management, Coordinator, and Director Team levels as critical to improving science communication. In smaller working teams and within larger Project Work Teams these continuing discussions make the direct connections between science and resource management clearer. We question the usefulness of one-off appraisals or evaluations from oversight entities absent an on-going commitment to continue the engagement and seek resolution to shortcomings in IEP activities, analyses, or resource investment processes as part of regular, recurring collaboration. IEP is working to foster deeper relationships, not only among agency staff and all the levels within agencies, but with our other stakeholders as well. The history of IEP has included many difficult decisions regarding monitoring investments and prioritizing research, and, moving forward, we will rely on these deeper long-term relationships to facilitate decision-making and have more effective communications that get to core issues.

Programmed flexibility is becoming a core and valued aspect of our IEP culture. Regular, ongoing reviews of ecological surveys with a priority on synthesis helps identify and refine management priorities with each review in turn. The timeliness of our reviews allows Agency Directors to adjust resources to support corresponding changes in implementation. We are receiving repeated requests to be flexible in the monitoring we perform (from, for example, the IEP Coordinators) to accommodate changes in crew resources to avoid COVID-19 restrictions, or to more closely conform to Incidental Take Permit terms and conditions, for example. This will require additional flexibility in contracting and more clarity from our written mandates to understand what can or cannot be changed in the IEP near-term. Longer-term plans can be developed and implemented for necessary changes that require more complex processes and inclusion in our science strategies.

As we look forward, we cannot help but look back at all the great accomplishments that this Program has made, accomplishments that depend on all the participants and partners of IEP. As we step through 2021, we are not fearful, we're hopeful, and we hope that you all will continue to broaden the IEP community feel, be effective and efficient, and keep IEP relevant.

OF INTEREST TO MANAGERS

This issue of the newsletter features the following science articles:

The Pilot Long-Term Monitoring Review Effort

The 2019-2020 IEP Long-Term Monitoring Review effort is summarized in an essay by **Jereme Gaeta (IEP & CDFW)** and colleagues in which they discuss the lessons learned from the novel pilot review effort. The essay serves as an introduction to and an overview of IEP Technical Report No. 96, in which they evaluated midwater and otter trawl long-term monitoring performed by the CDFW Fall Midwater Trawl survey, the University of California – Davis Suisun Marsh Study, and the CDFW Bay Study.

2019–2020 Delta Juvenile Fish Monitoring Program - Nearshore Fishes Annual Report

The non-salmonid nearshore fish assemblage sampling across the Delta and Bay is evaluated in a data report by **Ryan McKenzie (USFWS)**. The author describes the status and trends of Bluegill, Largemouth Bass, Inland Silverside, Sacramento Pikeminnow, Sacramento Sucker, Sacramento Splittail, California Halibut, and Surf Smelt from 1995 through 2020.

2019 Delta Juvenile Fish Monitoring Program - Salmonid Annual Report

Juvenile salmonid sampling across the Delta and Bay is evaluated in a data report by **Ryan McKenzie (USFWS)**. The author describes run-specific status and trends from 2000 through 2019 including seasonal patterns during the 2019 field season (August 2019 - July 2019).

2018-2019 Yolo Bypass Fisheries Monitoring Status and Trends Report

The 2019 water-year Yolo Bypass fish community, dominated by Threadfin Shad, is described in a data report by **Nicole Kwan (DWR)** and colleagues. They describe fish community patterns in the community across the water year in the context of environmental conditions, including hydrology and water quality, with an emphasis on floodplain connections.

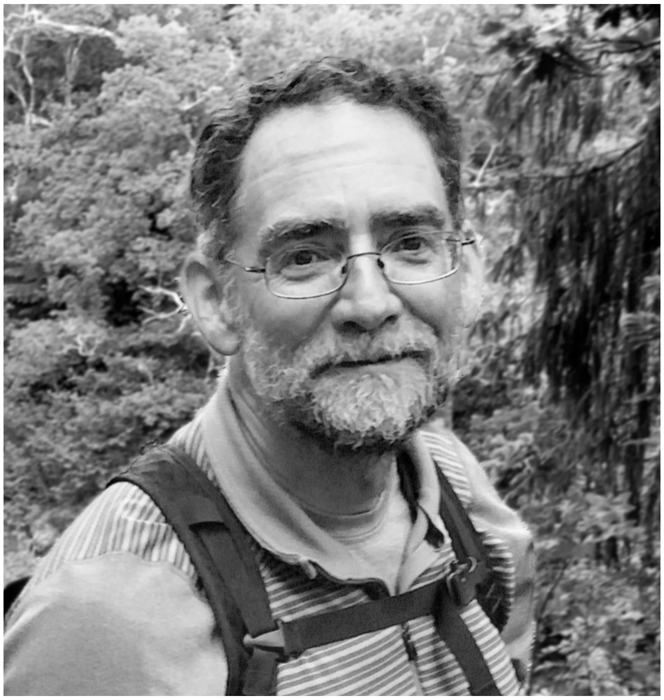
2019 Phytoplankton Status and Trends Report

The San Francisco Estuary algal community and pigments throughout 2019 is described in a spatially-explicit data report by **Tiffany Brown (DWR)**. The author identifies pigment maxima during spring and summer and a algal community dominated by cyanobacteria (>98%).

LETTERS, ESSAYS, AND OPINIONS

LETTER: Dr. Larry Brown: A Remembrance

Ted Sommer (DWR)
Louise Conrad (DSC)
Steven Culberson (IEP & DSC)
Fred Feyrer (USGS)
Bruce Herbold
Peter Moyle (UCD)
Anke Mueller-Solger (USGS)



This issue of the IEP Newsletter is dedicated to our beloved friend and colleague Dr. Larry Brown, who died February 10, 2021 while visiting his parents in Arizona. Larry was dealing with a recent death in his family and was looking forward to phased retirement starting this June.

Simply put, Larry was one of the single most important scientists working on the Bay-Delta. He was widely recognized as one of the regional experts in native fishes. Even more impressive, though, was the breadth of work in his career, which includes multiple disciplines such as hydrology, climate science, modeling, and invertebrates. Larry had extensive experience working outside the Bay-Delta watershed, including distant locations such as the Santa Ana River and Eel River. This background is reflected in his publication list, likely one of the longest and most diverse among agency scientists. At the time of his passing, Larry had amassed over 80 publications, a stunning achievement.

We also hope that the science community is aware of how influential Larry was in guiding Bay-Delta management. His research on native fishes and Bay-Delta ecology was instrumental in multiple listing and water rights reviews. Similarly, his early reviews of wetland science (Brown 2003a,b) were foundational documents for current tidal wetland restoration activities. More recently, his leadership on flow research has been very helpful for the development of Federal Endangered Species Act Biological Opinions and California Endangered Species Act Incidental Take Permits. For example, Larry guided the development of major flow science synthesis reports for the Fall Low-Salinity Habitat (Brown et al. 2014) and the Flow Alteration - Management, Analysis, and Synthesis Team projects (FLoAT MAST, In press). Larry was also a leader in a major synthesis report on Delta Smelt biology that produced updated conceptual models for the species (IEP-MAST 2015). The synthesis report, which included contributions from multiple scientists, was foundational to the California Natural Resource Agency’s Delta Smelt Resiliency Strategy (CNRA, 2016). These reports were huge achievements, requiring his leadership of interdisciplinary, multi-agency synthesis teams, and the responsibility of the majority of writing responsibilities. The products have had cascading influences on management of the Bay-Delta that will persist for decades.

Larry's role in supporting IEP and the Bay-Delta science enterprises were equally important as his contributions to management. He was always helpful in his role as a mentor and resource to junior agency scientists and numerous grad students, many of whom were guided by his input as a thesis or dissertation committee member. Larry was also a key representative for U.S. Geological Survey in supporting the IEP. He was a regular attendee at the IEP Science Management Team and chaired many project work teams. Larry has also served on numerous science panels for Delta Science Program, CALFED, and other organizations, providing expert recommendations on how to improve Bay-Delta science activities.

Larry's style of leadership was always unassuming and humble, and he led by doing hard work; because of this, members of the team would naturally realize that if they were going to participate, they too should make substantive contributions. When serving as a leader for large and interdisciplinary groups, Larry had an unmatched ability to weave together the contributions from multiple and diverse experts and create a cohesive, informative narrative. Through his leadership and hard work, Larry quietly provided not only a synthesis of scientific information but also promoted cohesion within the scientific community.

Larry was involved in so many aspects of the IEP and led so many crucial efforts at synthesis and scientific work that it is literally impossible to think of the IEP without his input over the last 25+ years that we knew him. He led several of our most controversial and convincing IEP Project Work Teams and had an ability to communicate complex issues to widely divergent and differently educated constituencies with remarkable deftness. Through all this, his calm and competent leadership has been a guiding light for all of us who aspire to use science as an organizing way of thinking and life. We therefore expect that his legacy will continue to inform current and future generations of IEP scientists about how to navigate the complex and contentious world of the Bay-Delta.

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ESSAY: The Pilot Long-Term Monitoring Review Effort

Jereme W Gaeta* (IEP & CDFW)
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Background and Motivation

The Interagency Ecological Program (IEP) Directors and Coordinators requested a formal review of IEP long-term monitoring elements (LTMEs) beginning in the first quarter of 2020 in response to stakeholder calls for regular, periodic reviews of LTMEs and as outlined in the IEP “Business Practices Review” (GEI Consultants, 2015). Because of the number of IEP compliance or status and trends surveys and the complexity of the potential review effort, we decided to conduct a pilot review in 2020 to determine the level of engagement and resources needed across IEP management entities to produce a useful and implementable review.

One key objective of the pilot review was to demonstrate that the correct balance of independent critical insight and properly informed IEP personnel could be brought together to effectively review IEP surveys in a timely, resource-responsible, and scientifically credible manner. Another important proving point was that logical groupings could be made for surveys using similar gear or targeting similar habitats or species to identify any redundancies or gaps in LTME designs. We assumed that several functionally related surveys could be reviewed effectively as a group and decided to focus on three midwater and otter trawl-based IEP surveys: CDFW’s Bay Study, UC Davis’ Suisun Marsh study, and CDFW’s Fall Midwater Trawl survey (Figure 1).

Among the suite of questions for which the review team was charged, the primary motivating questions were as follows:

1. What is the level of scientific rigor of the surveys for addressing documented needs for its data?
2. Do the surveys inform relevant needs of decision makers?
3. Do potential redundancies in monitoring exist, and how might programs increase efficiencies in monitoring?

Despite these motivating questions, the review team had no definitive endpoint or a priori expectation of findings; rather, we allowed preliminary findings presented at our weekly technical meetings and subsequent discussions guide the direction of the review. Indeed, we quickly realized the targeted time frame of just one year to compile the data, perform analyses, and write the report were in direct conflict with the potential vastness in scale and scope of the motivating questions. *To this end, our effort steered away from explicit recommended changes to individual surveys and, instead, focused on the development of transparent and reproducible analytical approaches and quantitative tools appropriate for subsequent efforts (with a longer time frame) to evaluate the design of monitoring programs*.

Pilot Review Analytical Framework

The LTMEs we reviewed are a portion of the IEP core long-term status and trends monitoring enterprise that collects data regarding abundance and distribution of fishes in the San Francisco Estuary. We thought a catch data driven community-based approach to evaluate surveys performance represented a reasonable perspective from which base our analysis and interpretation. Such an approach provides additional perspective beyond those used in previous internal and external IEP survey reviews where evaluations tended to focus on addressing ecology-based questions, rather

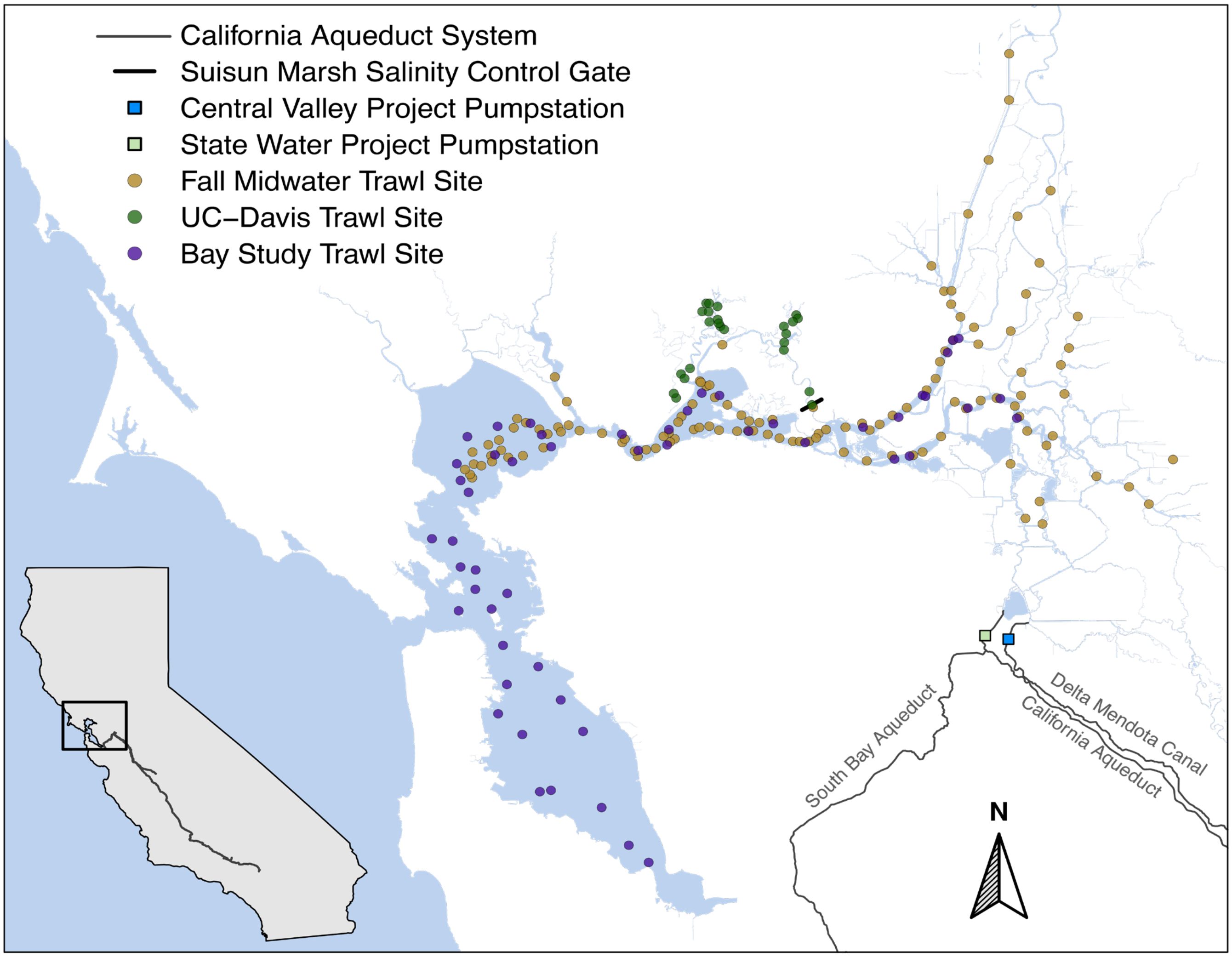

Figure 1: Map of the San Francisco Estuary shown with study-specific stations evaluated in the 2020 Pilot Long-Term Monitoring Review effort. Fall Midwater Trawl stations were surveyed via midwater trawl, UC-Davis trawl stations were surveyed via otter trawl, and Bay Study trawl stations were surveyed via midwater and otter trawls. Only stations surveyed ≥9 of most recent 10 years of available data as of the start of the pilot review in 2019 are shown (2009-2018).

than explicitly evaluating the character of the collected data at the outset. Since we opted for a data-oriented process to refine our analytical questions, we first considered catch data across all the sampled habitats, seasons, and years, for any species that are caught by the deployed gear – we did not begin with specific management outcomes or questions in mind. We chose to let our review of the three LTME datasets inform our process rather than be directed by historic or current LTME management goals or regulatory context (e.g., the Fall Midwater Trawl LTME began as a juvenile striped bass survey, but we felt the survey gear is effective at surveying the open-water fish community during the fall season as a whole).

From a purely analytical standpoint, an evaluation of potential redundancy in monitoring effort (e.g., do Fall Midwater Trawl stations that spatially overlap with the Bay Study provide additional information?) is feasible using a sensitivity analysis framework and, therefore, was one of the

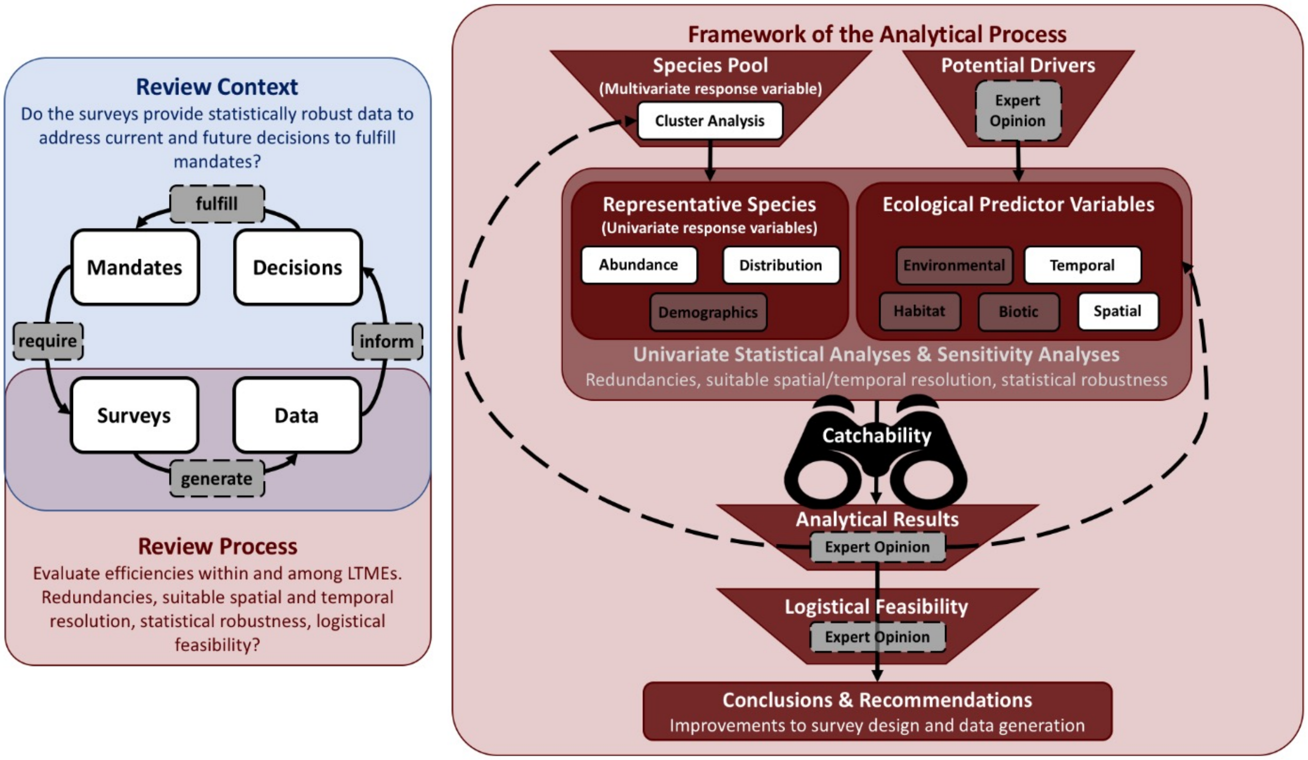

Figure 2. Review context and analytical framework used in the 2020 Pilot Long-Term Monitoring Review. NOTE: Survey data should be viewed through the "lens of catchability"; Catchability estimation is not currently contained in routine datasets or survey protocols.

primary deliverable targets of pilot review effort. To perform such an analysis, one would systematically remove a combination of stations and/or sampling events and evaluate whether your understanding of a variable (e.g., Sacramento Splittail catch over time) changes. However, while such methods are common for univariate data (i.e., a single species over time or across space) they are not available for multivariate datasets such as a fish community. The review team, therefore, developed the following analytical framework (Figure 2):

1. Identify and document nuances and caveats of each study and its data (see report Chapter 2)
2. Compile the disparate datasets into a unified format (see report Chapter 3)
3. Identify sub-community assemblages (while accounting for repeated sampling per station over time) and a representative species for each sub-community assemblage (that is, convert each sub-community from a multivariate data to single-species univariate data; see report Chapter 5)
4. Develop a single-species, univariate-based sensitivity framework (while accounting for repeated sampling per station over time; see review Chapter 6)

In short, this framework allowed us to condense the large number of fish species (>175) collected by these surveys into a manageable handful of representative species. As with all IEP LTMEs, however, the review highlights the fact that conclusions cannot be drawn about community or species status and trends nor potential monitoring redundancies without viewing the data through the lens of catchability (Figure 2). Specifically, detecting fishes can be complicated by the limitations of using nets towed behind boats to filter mobile organisms from the water column – organisms that may be too small at times to be caught in the mesh of the nets, too few or too patchy in distribution to be effectively represented in any one or even several net tows, or too variable in natural behavior to be predictably located at any one place over time or at predictable intervals. Collectively these issues can be combined under the term “catchability” (see review Chapter 4).

Findings and Recommendations

As data collection requires protocols and metadata, analysis and reporting require explicit discussion of assumptions and limitations when communicating ecological insight and inference. In the review effort reported in the 2020 pilot review report, for example, we evaluated LTMEs using midwater and otter trawl gear; consequently, any presentation or interpretation of our analytical findings must be viewed as only for fishes vulnerable to these gear at their survey locations and during the surveyed times. Similarly, we must be transparent and acknowledge that our findings are not applicable beyond these constraints.

Users of midwater and otter trawl-derived data should note that the spatial and temporal configuration of these monitoring programs has shifted over time in response to emerging issues and novel insights (see report Chapter 2). Collectively, these changes have resulted in varying consistency in spatiotemporal effort and the addition of new sampling locations, particularly deeper into the Delta (upstream). While some of these changes in spatiotemporal configuration were driven by adversity (e.g., reduced sampling frequency due to personnel or mechanical constraints), other changes highlight the responsiveness of the Interagency Ecological Program (IEP) to newly gained knowledge (e.g., sampling into the eastern and northern Delta to track Delta Smelt during drought conditions). Despite the adaptive nature of the history of these datasets, the long-term legacy they contain is invaluable. Any future changes to sampling regimes should be well documented and done with careful consideration in an effort to maintain their usefulness into the future. Nevertheless, we recommend that data users now and into the future delve beyond the metadata and develop a deeper understanding of the history of these monitoring programs prior to analysis.

Spatiotemporal trends in species abundance are the focus of the long-term monitoring surveys reviewed by the pilot effort in 2020. However, we recommend data users consider how trends based on count data from these surveys can be heavily influenced by variability in the observation process (i.e., catchability). In the pilot report, we demonstrated that, even with highly standardized field protocols (such as those implemented by many IEP monitoring programs), detection efficiency can still vary considerably through space, time, and among taxa (see review Chapter 4 for additional details and discussion).

We took advantage of historical data in our pilot review effort to simulate sampling reductions and evaluate the potential impact of such reductions on our ability to gain statistically-derived insights. We implemented our approach using a case study focused on Sacramento Splittail (a representative species identified by the sub-community assemblage analysis) abundance from the Bay Study and the UC Davis Suisun Marsh Study otter trawls, focusing on our ability to detect year-to-year changes in abundance within each season. We found in this case study that sampling reductions of 10% and 20% had little impact, although accuracy declined with further reductions. While these results demonstrated the utility of our approach, they are not generalizable and are only applicable to our ability to detect trends in Splittail abundance from Bay Study and UC Davis Suisun Marsh Study otter trawl data. A thorough analysis would require performing such simulations on multiple species and multiple parameters (fish abundance, distribution, length, habitat use, etc.). To this end, the model code we developed is readily available (see review Appendix D), and we welcome further exploration of potential sampling program modifications in concert with informed discussions at all levels of the IEP organization.

In closing, we are encouraged that the IEP management structure is receptive to learning how to revise long-term data collection activities to better meet regulatory and management needs. We are confident the tools developed and used during the pilot review effort will add to our ability to understand meaningful and efficient changes to the entire suite of IEP long-term monitoring elements and can serve as a foundation for subsequent review efforts. However, changes to a single LTME have the potential to influence other LTMEs, the long-term integrity of IEP's long-term monitoring program, and our understanding of the San Francisco Estuary. IEP must have the capacity to respond to changes in resources, analytical approaches, and emerging challenges, but a comprehensive revision and reconfiguring of LTMEs will only be successful if proposed revisions are built upon an understanding of the entirety of the IEP monitoring program and the value of the long-term data record. Change in the San Francisco Estuary is inevitable, but the knowledge and insights gained through systematic review is key to the IEP's success in confronting challenges and protecting the San Francisco Estuary into the coming decades and beyond.

Technical Report No. 96 Citation

IEP Long-term Survey Review Team. 2021. Interagency Ecological Program Long-Term Monitoring Element Review: Pilot approach and methods development (2020). IEP Technical Report No. 96. 206 pp.

Technical Report No. 96 can be downloaded from the Department of Water Resources Drop Box account.

Technical Report No. 96 can also be acquired by sending a report request to iep@wildlife.ca.gov.

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DATA REPORTS

2019–2020 Delta Juvenile Fish Monitoring Program - Nearshore Fishes Annual Report

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Introduction

The Delta Juvenile Fish Monitoring Program (DJFMP) of the United States Fish and Wildlife Service has monitored juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) within the Sacramento-San Joaquin Delta (Delta) since the mid-1970s. The original purpose of DJFMP was to evaluate the impact of water operations in the Delta on the survival, distribution, and outmigration timing of juvenile Chinook Salmon. However, with the growing recognition of importance of other members of the fish community in shaping ecosystem health and resilience, the objectives of DJFMP were expanded to include documenting the abundance and distribution of non-salmonid species in the Delta and San Francisco Bay (Bay).

The purpose of this report is to describe inter-annual abundance trends and distributional patterns of nearshore resident fishes within the Delta and Bay from 1995 to 2020. Currently, the DJFMP is one of the few long-term monitoring programs, surveying littoral habitats in the Delta and Bay, which makes the data valuable for a more holistic understanding of fish community changes (Nobriga et al. 2005) and documenting the expansion of non-native fishes in nearshore habitats (Moyle and Bennett 2008). Information on our salmonid catch trends can be found in the DFJMP Salmonid Annual Report. Due to the high species richness of our beach seine survey (>50 species), we limit our analyses on a rotating basis to six fish species within the Delta and two species within the Bay. This year, for the Delta we report on Bluegill (*Lepomis macrochirus*), Largemouth Bass (*Micropterus salmoides*), Inland Silversides (*Menidia beryllina*), Sacramento Pikeminnow (*Ptychocheilus grandis*), Sacramento Sucker (*Catostomus occidentalis*), Sacramento Splittail (*Pogonichthys macrolepidotus*) and for the Bay we report on California Halibut (*Paralichthys californicus*) and Surfsmelt (*Hypomesus pretiosus*). The complete DJFMP dataset, including environmental data not included in this report, and a description of sampling procedures are available at DJFMP's Environmental Data Initiative Data Portal (IEP et al. 2020).

Methods

Beach seines (hereafter, “seines”) were used by DJFMP to quantify the spatial distribution of fishes occurring in unobstructed nearshore habitats (i.e., beaches and boat ramps) throughout the Delta and Bay (Figure 1). A complete description of the historical and current methods is available on the DJFMP Environmental Data Initiative Data Portal (IEP et al. 2020). In this report we use relative site names in place of our traditional seine region numbers to aid in the spatial orientation of readers, thus: Seine Region 1 = Lower Sacramento River; Seine Region 2 = North Delta; Seine Region 3 = Central Delta; Seine Region 4 = South Delta; Seine Region 5 = Lower San Joaquin River; Region 6 = Bay Seine.

DJFMP conducted seining at fixed sites within regions once per week during daylight hours (between 6:00 am and 6:00 pm) with a 15.2 x 1.3 m net with 3 mm2 mesh, except for Bay Seines, which were sampled every other week throughout the year and a few North Delta seine sites, which were sampled three times per week from October 1 through the last week of January, to intensely monitor for juvenile winter-run Chinook Salmon

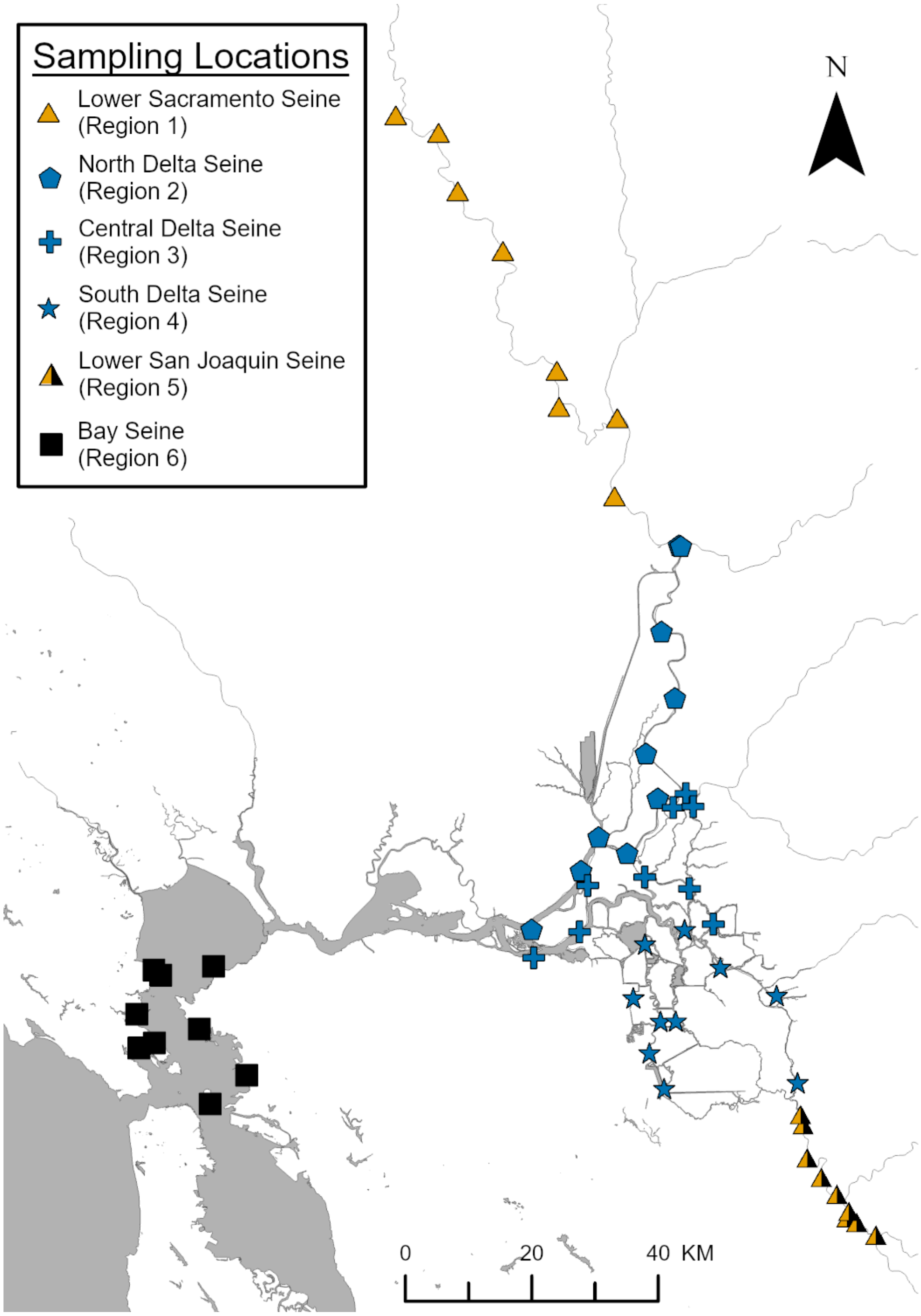

Figure 1: Overview map of United States Fish and Wildlife Service Delta Juvenile Fish Monitoring Program beach seine sites and sampling regions in the San Francisco Estuary, California, United States of America.

entering into the Delta from the Sacramento River Basin. Captured fishes ≥ 25 mm fork length (FL) were measured to the nearest 1 mm FL (with the exception of a few species that can be easily identified at < 25 mm fork length). If more than 30 individuals of a species were captured, a subsample of 30 individuals were randomly selected and FL measured. The captured fish beyond the first 30 per species were counted, but not measured (referred to as a “plus count”). Size distribution histograms were plotted for each species and the percentage of juveniles captured and measured were calculated using minimum length at maturity values from the scientific literature. In cases where minimum length at maturity was not reported in FL, we used the total length or standard length value reported in the literature. Water quality variables (i.e., water temperature, dissolved oxygen, turbidity, and conductivity) were measured immediately after each seine haul. Our environmental data is not included in this report but is publicly available online at the DJFMP EDI Portal (IEP et al. 2020).

Before estimating catch-per-unit-effort (CPUE), we filtered the dataset by excluding samples collected during poor sampling conditions, such as twists in the net or snags (i.e., gear condition code > 2 in the DJFMP dataset), and outliers in sampling volumes identified by exceedance of maximum seine net dimensions. To compare the CPUE of species across space and time we calculated mean annual CPUE values for each seine region. The mean annual CPUE values were calculated with a series of averages of averages to avoid overweighting sampling sites due to differences in sampling frequency. First, we calculated a sample CPUE value for each species by dividing the total number of individuals caught of that species by the total volume of water sampled for each sample taken at each seine site:

$$\begin{aligned}\text{Sample Volume } (\text{m}^3) &= \text{Seine Width (m)} \times \text{Seine Length (m)} \\ &\quad \times \text{Seine Depth (m)} \times 0.5\end{aligned}$$

$$\text{Sample CPUE}_{i_j} = \frac{\text{Count}_{i_j}}{\text{Sample Volume } (\text{m}^3)}$$

where *i* indexes species and *j* indexes seine sites. We then averaged sample CPUE values within each site by month to calculate a mean monthly CPUE for each site:

$$\overline{\text{Monthly CPUE}_{i_j}} = \frac{\sum_{\text{Site:Month}} \text{Sample CPUE}_{i_j}}{\text{N}}$$

where *i* indexes species and *j* indexes seine sites. We then averaged the mean monthly site CPUE values within each seine region by month to calculate a mean monthly CPUE for each region:

$$\overline{\text{Monthly CPUE}_{\,i_k}} = \frac{\sum_{\text{Region:Month}} \overline{\text{Monthly CPUE}_{i_j}}}{\text{N}}$$

where *i* indexes species, *j* indexes seine sites, and *k* indexes seine regions. We then calculated the mean annual CPUE values for each seine region by averaging monthly region CPUE values across months within each sein region by field year and expanded our mean CPUE values by 10,000 m3:

$$\overline{\text{Annual CPUE}_{i_k}} = \frac{\sum_{\text{Region:Field Year}} \overline{\text{Monthly CPUE}_{i_k}}}{\text{N}} \times 10{,}000$$

where *i* indexes species and *k* indexes seine regions.

Results and Discussion

Reduced Sampling in 2020

In 2020, the DJFMP seine sampling effort was severely reduced due to COVID-19 and smoke mitigation measures. In total, 676 out of 2300 scheduled seine hauls (29.2%) were completed across all seine regions and the percentage of sampling completed varied by region: Lower Sacramento River- 43.1%; North Delta- 34.2%; Central Delta- 32.4%; South Delta- 14.7%; Lower San Joaquin River- 17.7%; Bay Seine- 33.3%. Given the significant restriction in sampling, we advise readers to take this into account and use caution when interpreting the results for 2020.

Bluegill

Bluegill are native to the eastern and southern United States; however, after their introduction to California in the early 1900s, they have become one of the most widely distributed and abundant warm water species in the state (Moyle 2002). Their wide distribution and high abundance within the Delta may result from their ability to survive and reproduce under a wide variety of environmental conditions and habitat types. Bluegill are tolerant of high temperatures and low dissolved oxygen and are often found in association with rooted aquatic vegetation, which provides foraging opportunities and refugia from predators (Smale and Rabeni 1995; Dewey et al. 1997). While they exhibit a wide geographical range, they have limited local ranges throughout their lifespan (Klinard et al. 2018). Their wide distribution, high abundance, and opportunistic foraging strategy may limit the production of native species directly through predation on their larvae (Kim and DeVries 2001) and indirectly through competition for resources (Marchetti 1999). Introduced sunfishes, such as Bluegill, have been implicated as a primary driver of the extirpation of the Sacramento Perch (*Archoplites interruptus*) from the Central Valley of California due to competition (Marchetti 1999, Moyle 2002). Bluegill typically reach maturity at 1-3 years of age (Belk 1995), which corresponds to a size range of 45–136 mm FL in the Delta (Moyle 2002).

Since 1995, our seine surveys have captured Bluegill ranging from 16–202 mm FL with a median fork length of 54 mm (Figure 2). Juveniles (< 45 mm FL) made up 35.9% of measured individuals. Our estimated CPUE of Bluegill has generally remained low in the northern portions of our sampling range with low numbers observed in both the lower Sacramento River and the North Delta seines (Figure 3). The Sacramento River basin is generally colder and experiences higher flows than the San Joaquin River basin (Moyle 2002), which may minimize suitable habitat and the ability of warm-water species like the Bluegill to propagate. In the southern regions, CPUE has been more variable but, overall, we have seen moderate increases in the Central Delta and larger increases in the South Delta and the Lower San Joaquin River since 1995 (Figure 3). These areas are generally warmer and experience lower flows than the Northern regions (Moyle 2002). These trends

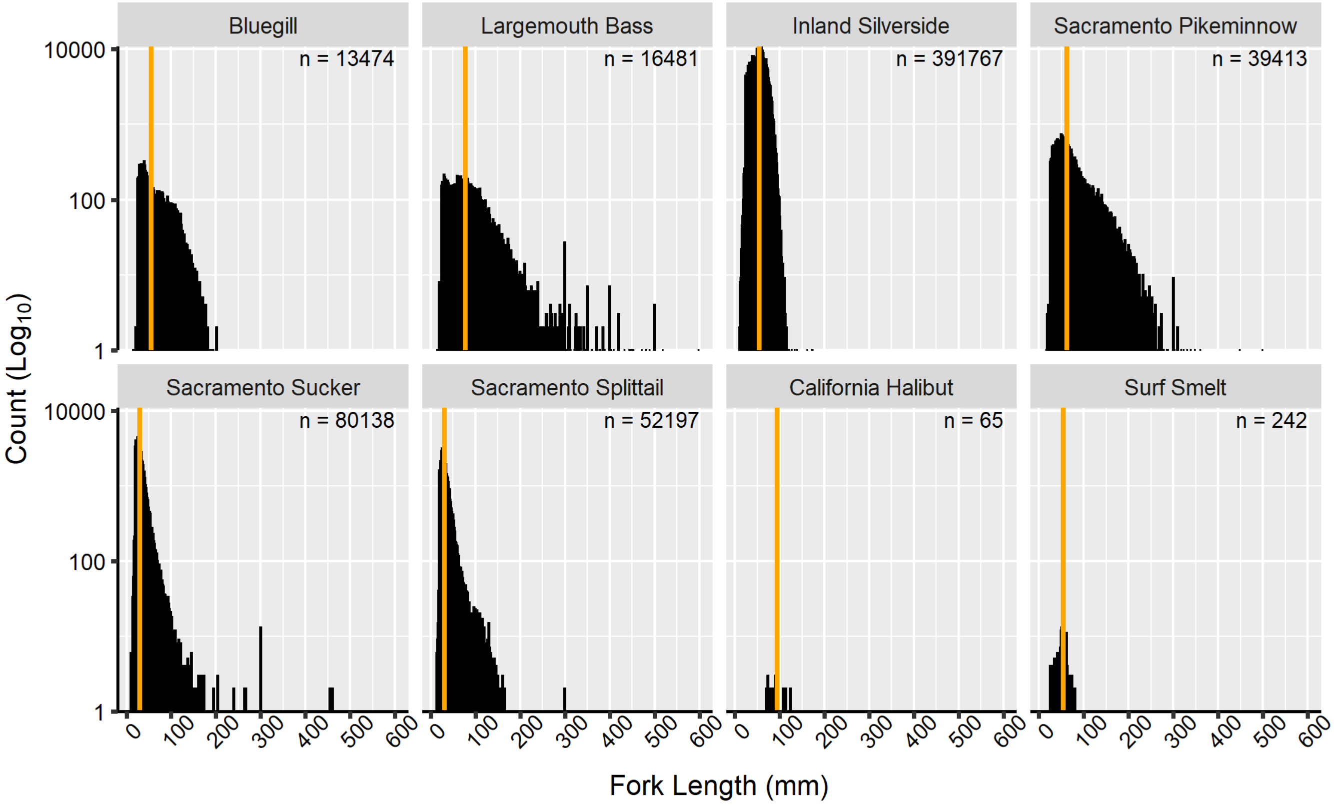

Figure 2: Size distribution of measured fish from 1995–2020 United States Fish and Wildlife Service Delta Juvenile Fish Monitoring Program beach seine surveys in the San Francisco Estuary. Median fork lengths are indicated with vertical orange line.

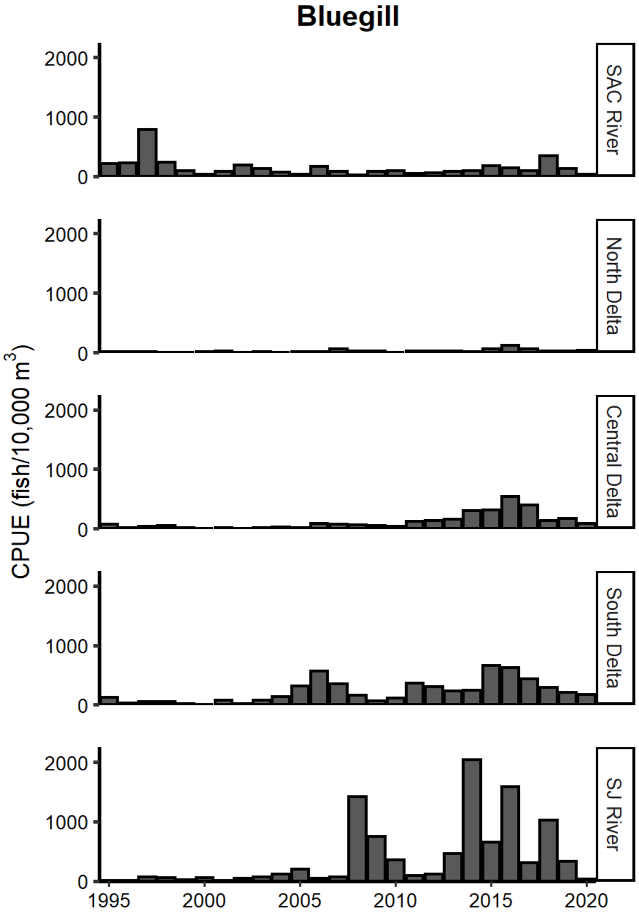

Figure 3: Annual catch-per-unit-effort (CPUE) of Bluegill (*Lepomis macrochirus*) in beach seine regions from 1995 to 2020. Sampling in 2020 was significantly reduced due to COVID-19 mitigation and results should be interpreted with caution.

are in agreement with past studies that have suggested that environmental conditions and the expansion of invasive submerged aquatic vegetation in the Southern regions of the Delta (Khana et al. 2015) have been conducive to the expansion of warm-water non-native species such as the Bluegill (Brown and Michniuk 2007, Conrad et al. 2016).

Largemouth Bass

Largemouth Bass are native to eastern North America and were introduced to California in the 1890s (Moyle 2002). While they have been present in the Delta for over a century, Largemouth Bass abundance within the system seems to have increased concurrently with the proliferation of the invasive weed Egeria densa (Brown and Michniuk 2007, Conrad et al. 2016, Mahardja et al. 2017). Their large gape size and flexible foraging behaviors have allowed Largemouth Bass to become an apex predator in nearshore areas of the Delta. Although Largemouth Bass are often found in association with non-native species and may have lower spatial overlap with native fish species than other predators, they can be effective predators of native fish in the Delta under certain circumstances (Nobriga and Feyrer 2007). Therefore, increases in abundance and distribution of this species may further imperil a variety of native fishes within the Delta. Largemouth Bass begin to reach maturity at 180–250 mm total length (Moyle 2002).

Since 1995, our seine surveys have captured Largemouth Bass ranging from 16–600 mm FL with a median of 78 mm FL (Figure 2). Juveniles (< 180 mm FL) made up 96.2% of measured individuals. Similar to the Bluegill, we have observed increases in the CPUE estimates of Largemouth Bass in the Central and South Delta and the Lower San Joaquin River regions; in fact, the CPUE was the highest on record for the Central Delta in 2019 and the San Joaquin River in 2020 (Figure 4). The CPUE of Largemouth Bass in the North Delta has remained relatively low since 1995, however we have seen an increase in the Lower Sacramento River which feeds into the North Delta region. These results suggest that juvenile Largemouth Bass likely recruit to the Northern Delta from nearby areas; however, they do not persist in the North Delta's nearshore habitats sampled by seines. We observed a similar trend with Bluegill and may indicate that the environmental conditions and/or habitats in the North Delta remain inhospitable to warm-water centrarchids.

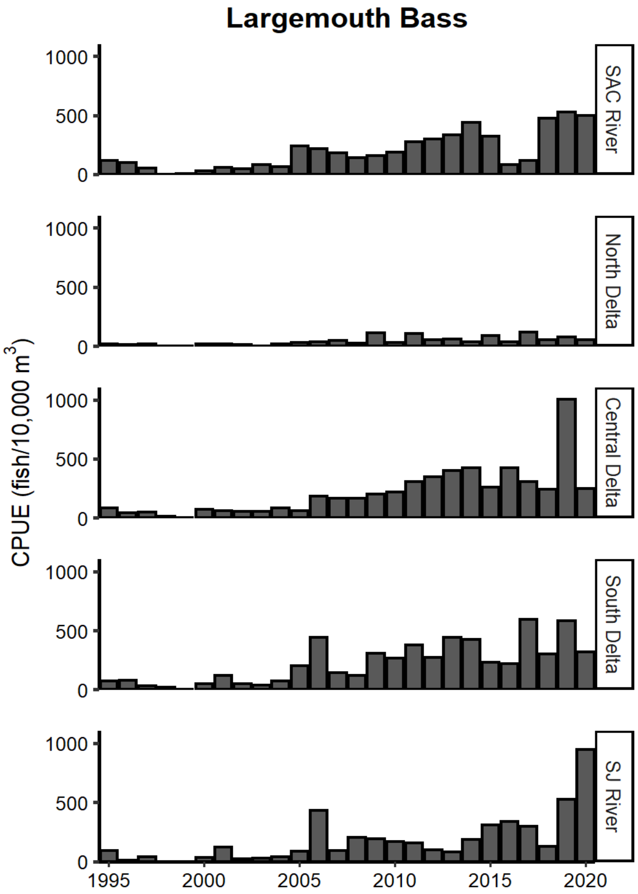

Figure 4: Annual catch-per-unit-effort (CPUE) of Largemouth Bass (*Micropterus salmoides*) in beach seine regions from 1995 to 2020. Sampling in 2020 was significantly reduced due to COVID-19 mitigation and results should be interpreted with caution.

Inland Silversides

Inland Silversides are native to eastern North America and became established in the Delta in the mid-1970s, and are currently one of the most prolific species in the system (Moyle 2002). They can tolerate a wide variety of environmental conditions (e.g., salinity, temperature), but are often found in shallow nearshore areas where they shoal (Moyle 2002). While their impacts on native populations are not well understood, they may reduce them directly via larval predation (Schreier et al. 2016) and/or indirectly through competition for limited food resources (i.e., zooplankton; Moyle 2002). Inland Silversides begin to reach maturity at 47.6–62.5 mm standard length (Middaugh and Hemmer 1992).

Since 1995, our seine surveys have captured Inland Silversides ranging from 11–176 mm FL with a median fork length of 54 mm (Figure 2). Juveniles (< 47.6 mm FL) made up 36.5% of measured individuals. Estimated CPUE has shown some variability from year to year, but, in general, we have observed increased CPUE in all seine regions since 1995 (Figure 5). Unlike the warm-water centrarchids discussed earlier, an increase in CPUE of this invasive species was observed in the North Delta Region from 2014 to 2018 (Figure 5). This increase followed multiple years of drought which may have facilitated

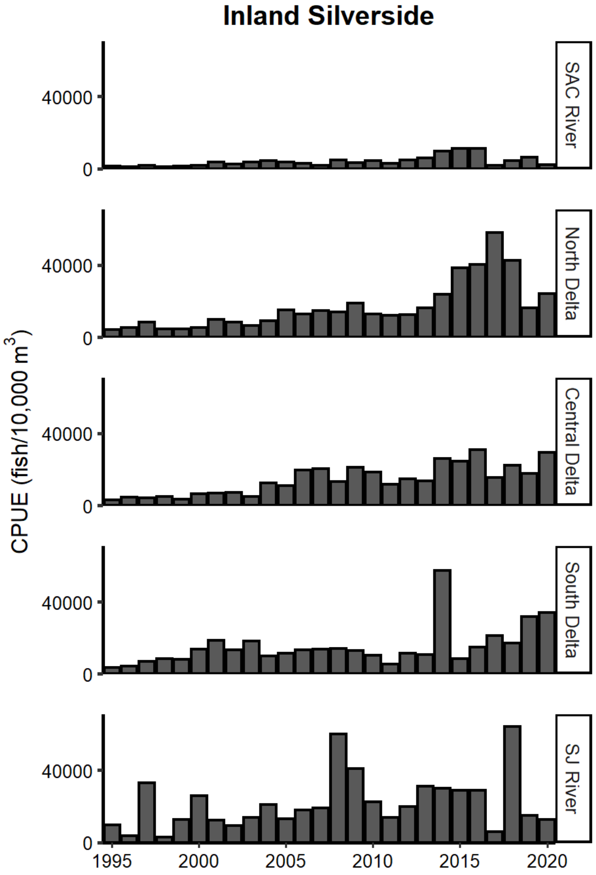

Figure 5: Annual catch-per-unit-effort (CPUE) of Inland Silversides (*Menidia beryllina*) in beach seine regions from 1995 to 2020. Sampling in 2020 was significantly reduced due to COVID-19 mitigation and results should be interpreted with caution.

the expansion of populations within the North Delta region. In 2019 and 2020 we observed a decrease in CPUE in the North Delta and the Lower San Joaquin River. The decrease in CPUE may have been influenced by the higher flows in 2019 resulting from higher-than-average precipitation (CDWR 2021). We also observed a decrease in the Lower San Joaquin River during the high precipitation year of 2017. Past research has shown that higher spring outflows correlate to lower Silverside abundance (Mahardja et al. 2016). However, we do not observe this inverse relationship between CPUE and outflow in every year, as we observed an increase in CPUE in the North Delta in the wet water year of 2017. Given the proliferation of this species in the Delta, and its possible harmful impacts to native species, future research is warranted to better understand the environmental conditions (e.g. outflow, nearshore habitat) affecting the distribution of this species.

Sacramento Pikeminnow

Sacramento Pikeminnow are large, long-lived cyprinids endemic to California (Moyle 2002). They are migratory and spawn in major tributaries of the Delta in March through May. After hatching, juveniles disperse downstream where and rear in backwater habitats. The Delta is hypothesized to serve as important rearing ground for age-1+ fish with flow levels related to how many rear in the region (Nobriga et al. 2006). Overall, the Delta's main source of Sacramento Pikeminnow is the Sacramento River with negligible contributions from the San Joaquin River except in years with high flow (Brown and Michniuk 2007). Sacramento Pikeminnow are opportunistic feeders that may forage on a variety of prey types throughout the water column, however, they display an ontogenetic shift to a higher proportion of fishes. Prior to the introduction of Striped Bass (Morone saxatilis) and Largemouth Bass, Sacramento Pikeminnow were apex predators in the Delta (Moyle 2002). Sacramento Pikeminnow begin to reach maturity at 220–250 mm standard length (Moyle 2002).

Since 1995, our seine surveys have captured Sacramento Pikeminnow ranging from 17–500 mm FL with a median fork length of 62mm (Figure 2). Juveniles (< 220 mm FL) made up 99.5% of measured individuals. Trends in Sacramento Pikeminnow populations have generally remained consistent since 1995 with the highest estimates of CPUE occurring in the Lower Sacramento River followed by the North Delta and Central Delta Regions (Figure 6). In 2019, we observed an increase in Pikeminnow catches for both the Lower Sacramento and San Joaquin River regions suggesting that it was a relatively good year for production

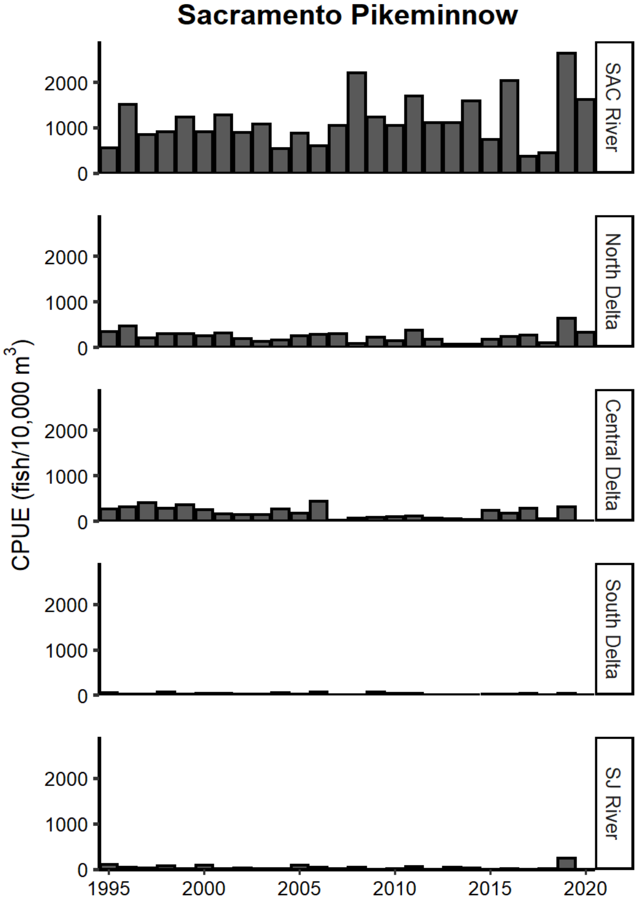

Figure 6: Annual catch-per-unit-effort (CPUE) of Sacramento Pikeminnow (*Ptychocheilus grandis*) in beach seine regions from 1995 to 2020. Sampling in 2020 was significantly reduced due to COVID-19 mitigation and results should be interpreted with caution.

in the upper tributaries. In 2020, relative abundance was in-line with past years in the Lower Sacramento River and North Delta, and generally absent in the Central Delta, South Delta, and San Joaquin River seine regions (Figure 6).

Sacramento Sucker

Sacramento Sucker are long-lived catostomids native to the Delta (Moyle 2002). They may inhabit a variety of freshwater habitats but are most abundant in cool streams and rivers with low turbidity. In general, Sacramento Sucker migrate into major tributaries where they spawn on riffles between February and June. Their recruitment success is thought to be highest when high flows increase spawning and rearing habitat and provide refugia from predators (Moyle 2002). After emerging, larvae are flushed downstream to areas (i.e., warm shallows, flooded vegetation) where they may rear for multiple years. Due to their ability to tolerate a variety of environmental conditions and their high recruitment success when conditions are favorable, they are one of the few native species that maintained relatively high numbers within the highly modified Delta. Sacramento Sucker begin to reach maturity at 200–320 mm FL (Moyle 2002).

Since 1995, our seine surveys have captured Sacramento Sucker ranging from 11–565 mm FL with a median fork length of 30mm (Figure 2). Juveniles (< 200 mm FL; citation) made up 99.9% of measured individuals. The trends in Sacramento Sucker since 1995 have generally remained consistent, with the highest estimates of CPUE observed in the Lower Sacramento River followed by lower abundances in the North Delta, Central Delta, Lower San Joaquin River, and the lowest abundance observed in the South Delta (Figure 7). These patterns are very similar to the Sacramento Pikeminnow and suggest that the upper tributaries on the Sacramento River have remained a critical component to the reproduction and population dynamics of these native species. In 2019, we observed a strong year class compared to the previous few years as CPUE increased in all regions. Similar to Sacramento Pikeminnow, CPUE was in-line with past years in 2020 for the Lower Sacramento River and North Delta, and generally absent in the Central Delta, South Delta, and San Joaquin River seine regions (Figure 7).

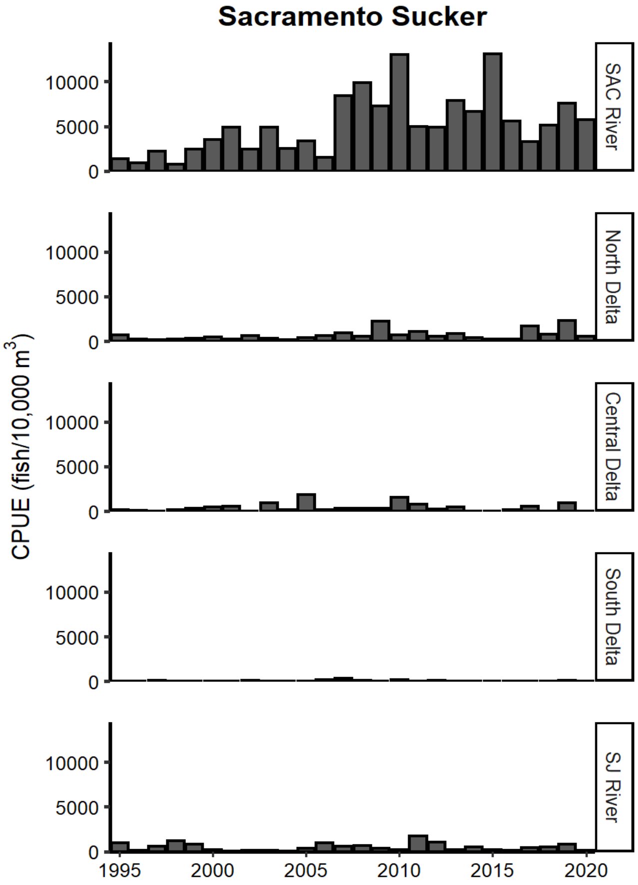

Figure 7: Annual catch-per-unit-effort (CPUE) of Sacramento Sucker (*Catostomus occidentalis*) in beach seine regions from 1995 to 2020. Sampling in 2020 was significantly reduced due to COVID-19 mitigation and results should be interpreted with caution.

Sacramento Splittail

Sacramento Splittail, are relatively large (> 40 cm FL) cyprinids native to the Delta and upper Sacramento and San Joaquin River Basins (Moyle 2002). Sacramento Splittail inhabit most areas of the Delta during periods of high abundance; however, when populations are low, they are generally confined to the North and Western Delta regions (Moyle et al. 2004). During the winter and spring, adults migrate upstream to forage and spawn in flooded areas. Sacramento Splittail display a boom and bust cycle in their populations as year class strength is positively correlated with wet water years, high Delta outflow, and flood plain inundation (Moyle et al. 2004). These large fluctuations in their populations partially led to their federal listing under the Endangered Species Act in 1999 and subsequent delisting in 2003 (Moyle et al. 2004). Although Splittail are not currently federally listed, they remain a species of special concern for the state of California and the Delta science community. Sacramento Splittail begin to reach maturity at the end of their second year, corresponding to a standard length of 170 mm (Moyle 2002).

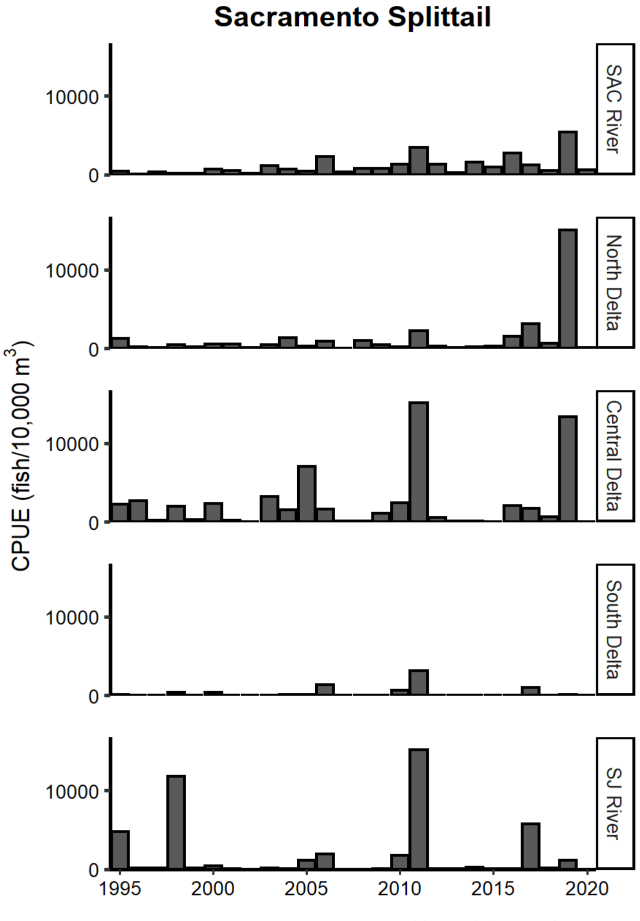

Figure 8: Annual catch-per-unit-effort (CPUE) of Sacramento Splittail (*Pogonichthys macrolepidotus*) in beach seine regions from 1995 to 2020. Sampling in 2020 was significantly reduced due to COVID-19 mitigation and results should be interpreted with caution.

Since 1995, our seine surveys have captured Sacramento Splittail ranging from 14–342 mm FL with a median fork length of 31 mm (Figure 2). Juveniles (< 170 mm FL) made up 99.9% of measured individuals. Since 1995, we have observed spikes in the CPUE estimates of Splittail in some years, which were preceded and followed by periods of lower abundance (Figure 8). This pattern is consistent their boom or bust life history strategy. In 2019 we observed a strong year class with high CPUE in the Lower Sacramento River, North Delta, and Central Delta regions. We also observed increases in CPUE in the Lower San Joaquin River and South Delta, however, the magnitude of increase was not as high as the other regions. These patterns are similar to the Sacramento Pikeminnow and Sacramento Sucker and overall suggest that environmental conditions in 2019 promoted increased levels of reproduction for many native fishes. In 2020, Sacramento Splittail were relatively absent in all seine regions except for the Lower Sacramento River.

California Halibut

California Halibut are large paralichthids native to the coastal waters of central and southern California, with the Bay being the Northern limit of their known spawning range (Haugen 1990). Adults generally undergo seasonal spawning migrations with individuals moving inshore to spawn during the spring and summer and offshore during the winter. Juveniles recruit to nearshore habitats where they rear for up to two years before moving to deeper waters. California Halibut do not tolerate combinations of low water temperature and salinity (14°C and 8 ppt, respectively; Madon 2002), so the timing and magnitude of freshwater input to the Bay and other regulators of water temperature and salinity are likely to affect recruitment and distribution from year to year. The California Halibut is considered an economically important species in California and supports both a commercial and recreational fishery. California Halibut begin to reach maturity at 257 mm FL (Lesyna and Barnes 2016).

Since 1997, our seine surveys have captured California Halibut ranging from 38–312 mm FL with a median fork length of 94 mm (Figure 2). Juveniles (< 257 mm FL; citation) made up 98.5% of measured individuals. Since 1997, we have observed low CPUE estimates of California Halibut in the Bay in most years (Figure 9). Interestingly, we observed peaks in CPUE from 2012 to 2016 which corresponded to periods of low Delta flow and higher salinity and warmer water temperature in the Bay (Work et al. 2017). In 2019, we observed a relatively high abundance of California Halibut in the Bay. In 2020, no California Halibut were detected in the Bay.

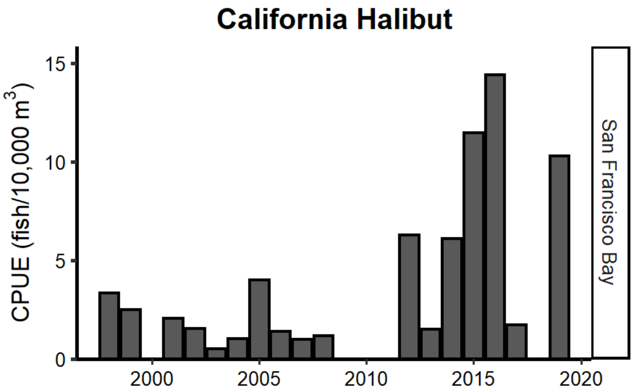

Figure 9: Annual catch-per-unit-effort (CPUE) of California Halibut (*Paralichthys californicus*) in beach seine regions from 1995 to 2020. Sampling in 2020 was significantly reduced due to COVID-19 mitigation and results should be interpreted with caution.

Surf Smelt

Surf smelt are native osmerids found in the coastal waters off of California to Alaska. Surf smelt live up to five years and many spawn at one year of age; the majority by two years of age (Pentilla 1978). Little to no spawning occurs within the Bay, however, spawning does occur along nearby coastal beaches during the fall and winter (Wang 2007). From late fall to spring, juveniles are found within nearshore areas of the Bay, which they use as foraging and rearing habitat. In the summer and early fall, juvenile surf smelt are generally absent from the Bay indicating that environmental conditions and warmer water temperatures during this period may be unsuitable (Baxter 1999). Surf smelt contribute to both commercial and recreational fisheries in California. Surf Smelt begin to reach maturity at 150–170 mm total length (Pentilla 1978).

Since 1997, our seine surveys have captured Surf Smelt ranging from 25–118 mm FL with a median fork length of 54 mm (Figure 2). Juveniles (< 150 mm FL) made up 100% of measured individuals. Since 1997, we have observed low CPUE, or absence, of Surf smelt in the Bay in most years (Figure 10). The highest CPUE estimates were observed in 1999, 2008, and 2011,

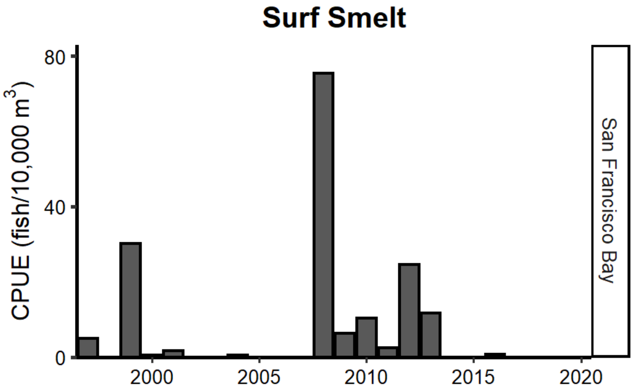

Figure 10: Annual catch-per-unit-effort (CPUE) of Surf Smelt (*Hypomesus pretiosus*) in beach seine regions from 1995 to 2020. Sampling in 2020 was significantly reduced due to COVID-19 mitigation and results should be interpreted with caution.

which correspond to one or two years after a high-water year (Sacramento and San Joaquin Valley, CDWR 2021). Given that most individuals begin spawning at 1 or 2 years of age, this observation suggests that successful recruitment may be linked to Delta inflow in some years. Since 2014, Surf Smelt have been generally absent from our seine survey, indicating that the low water years and corresponding higher temperatures and salinities observed in the Bay from 2013 to 2015 (Work 2017) may have had detrimental effects on recruitment. In 2019 and 2020, no Surf Smelt were detected in seines.

Management Implications

Since 1995, the DJFMP nearshore fish survey has documented the abundance and distribution of non-salmonid species in nearshore habitats of the Delta and Bay. The data collected by the survey allows resource managers and researchers to track changes in the distribution and relative condition of nearshore fish populations across time and space, and environmental conditions and management activities. Therefore, the DJFMP nearshore fish survey remains a critical component of fish management and conservation within the Delta and Bay. The full DJFMP dataset, including environmental data not included in this report and a description of sampling procedures are available at DJFMP's Environmental Data Initiative Data Portal (IEP et al. 2020).

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2019 Delta Juvenile Fish Monitoring Program - Salmonid Annual Report

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Introduction

Out-migrating juvenile Chinook Salmon (*Oncorynchus tshawytscha*) and Steelhead (*O. mykiss*) of the Central Valley, California, must travel from their upstream natal tributaries into the Sacramento-San Joaquin Delta (Delta) prior to reaching the Pacific Ocean to rear in the marine environment. The Central Valley Project (CVP) and State Water Project (SWP), water operation projects that supply water to over 27 million Californians, have the potential to affect these salmonids and their rearing habitats throughout the Delta (Kimmerer 2008; NMFS 2009,2019). The effects of these water operations, in part, depends on the timing and distribution of salmonids throughout the system, which can be highly variable from year to year due to a variety of environmental factors (Munsch et al. 2019). Since 1976, the U.S. Fish and Wildlife Service's Delta Juvenile Fish Monitoring Program (DJFMP) has monitored the annual timing, distribution, and relative abundance of juvenile salmonids throughout the Delta to better our understanding, inform the management, and mitigate the impacts of the CVP and SWP water export operations on their populations.

The purpose of this report is to provide a brief communication on the distribution of juvenile salmonids observed during the DJFMP 2019 field year (August 2018 to July 2019) in terms of their: 1) immigration into the Delta; 2) residency within the Delta; and 3) emigration from the Delta.). Information on our non-salmonid catch trends can be found in the DFJMP Nearshore Fishes Annual Report. The complete DJFMP dataset—including environmental data not included in this report—and a complete description of sampling procedures is available at DJFMP's Environmental Data Initiative Data Portal (IEP et al. 2020).

Methods

Over the years, the DJFMP has used a variety of gear types deployed at different time periods and frequencies throughout the year to examine the temporal and spatial distribution of fishes throughout the littoral and in-channel habitats of the Delta and greater San Francisco Estuary (Figure 1). A complete description of the historical and current methods is available at the DJFMP Environmental Data Initiative Data Portal (IEP et al. 2020). In this report, we use relative

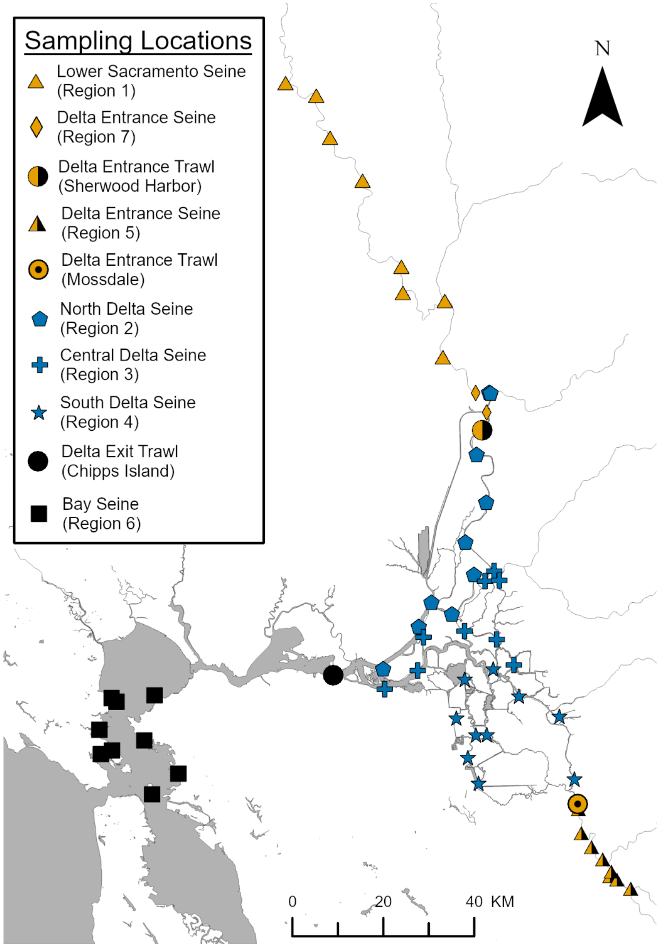

Figure 1: Long-term sampling sites for the United States Fish and Wildlife Service Delta Juvenile Fish Monitoring Program in the San Francisco Estuary, California, United States of America.

site names in place of our traditional beach seine region numbers and trawl site names to aid in the spatial orientation of readers, thus: Seine Region 1 = Lower Sacramento; Seine Region 2 = North Delta; Seine Region 3 = Central Delta; Seine Region 4 = South Delta; Seine Region 5 = Delta Entrance Seine (San Joaquin River Basin); Region 6 = Bay Seine; Seine Region 7 = Delta Entrance Seine (Sacramento River Basin); Sherwood Harbor Trawl = Delta Entrance Trawl (Sacramento River Basin); Mossdale Trawl = Delta Entrance Trawl (San Joaquin River Basin); Chipps Island Trawl = Delta Exit.

During the 2019 field year the DJFMP used a combination of beach seines (hereafter referred to as "seine") and surface trawling (mid-water and Kodiak trawls) to monitor the distribution of juvenile salmonids (Figure 1). Monitoring was conducted year-round during daylight hours (between 6:00 am and 6:00 pm), except for the Delta entrance seine (Sacramento River Basin; discussed below). Typically, ten 20-min trawls were conducted a minimum of three days per week at each trawling site and all seine sites were sampled once per week, except for: 1) Bay Seines, which were sampled every other week throughout the year, and 2) Delta entrance seines (Sacramento River Basin) and a few North Delta seines, which were sampled three times per week from October 1 through the last week of January, to intensely monitor juvenile winter-run Chinook Salmon entering into the Delta from the Sacramento River Basin. The California Department of Fish and Wildlife (CDFW) sampled the Delta entrance trawl site (San Joaquin River Basin) in place of DJFMP between the months of April and June following similar methods. Data collected from both DJFMP and CDFW efforts are included in this report.

Captured fishes ≥ 25 mm fork length (FL) were measured to the nearest 1 mm FL (except for a few species that can be easily identified at < 25 mm fork length). The race of all unmarked juvenile Chinook Salmon were determined using the river Length at Date Criteria (LDC) developed by Fisher (1992) and modified by Greene (1992), except for individuals captured at the Delta entrance trawl site (San Joaquin River Basin); and Lower San Joaquin River Seine Region. These individuals were classified as non-winter-run regardless of LDC since winter-run Chinook Salmon are not known to occur within the San Joaquin River and its main tributaries (Yoshiyama et al. 1998). If more than 50 individuals of a Chinook Salmon race were captured, a subsample of 50 individuals were randomly selected and measured. The rest of the captured fish were counted, but not measured. All juvenile salmonids with missing (i.e., clipped) adipose fins, pelvic fin clips (used to mark a specific brood stock of winter-run hatchery fish in some years), and other forms of marks or tags (e.g., stain dye, disc tags, acoustic tags) were recorded as marked along with their respective marking type. All juvenile Chinook Salmon with missing adipose fins observed and intact pelvic fins were considered hatchery-reared and were brought back to the lab for coded wire tag extraction, race determination and origin via the Regional Mark Information System database (RMIS 2021). Juvenile Chinook Salmon with missing adipose fins and pelvic fin clips were recorded as hatchery-reared winter-run and were released. Juvenile Steelhead with missing adipose fins were recorded as hatchery-reared and were released. Water quality variables (i.e., water temperature, dissolved oxygen, turbidity, and conductivity) were measured immediately before each trawl and during or after each seine haul but are not included in this report.

Before estimating catch-per-unit-effort (CPUE), we filtered the dataset by excluding samples collected during poor sampling conditions, such as twists in the net or major cod-end blockages (i.e., gear condition code > 2 in the DJFMP dataset), when debris was present on flow meters, and outliers in sampling volumes. For seines, volume outliers were identified by the exceedance of the standard minimum and maximum seine net dimensions set by the DJFMP standard operating procedures for seines. For trawls, volume outliers were identified as values that were more than 1.5 times the interquartile range above the third quartile or below the first quartile of pooled volumes by trawl site using the boxplot.stats function in R (R Core Team 2021). Our outlier checks resulted in 3,261 out of 96,193 trawl (3.3 %) and 24 out of 41,157 (< 1%) seine samples being removed from our final dataset. The high number of outliers in the trawl dataset were likely due to transcription errors and intermittent debris on flow meters during sampling. All juvenile salmonids with missing (clipped) adipose fins were treated as marked hatchery fish in our dataset. Salmonids used in directed studies that possessed other forms of marks or tags (e.g., stain dye, disc tags, acoustic tags), were not considered part of regular hatchery releases and were excluded from our catch dataset to avoid biasing our calculations of the proportion of hatchery and wild origin fish in samples. Since 1998, all juvenile winter-run Chinook and Steelhead produced from California hatcheries have been adipose fin clipped; therefore, all unmarked individuals were classified as wild origin (USFWS 2011, NMFS 2014). For non-winter-run Chinook Salmon, we estimated the number of unmarked hatchery fish in samples collected after the 2008 implementation of the Central Valley Constant Fractional Marking Program using the methods detailed in Graham et al. (2018). Before 2008, non-winter run Chinook Salmon were classified as unknown origin fish.

To compare the relative abundance of juvenile salmonids across space and time, we calculated mean monthly and annual volumetric catch-per-unit-effort (CPUE) values for each seine region and trawl site. The mean monthly and annual CPUE values were calculated with a series of averages of averages to avoid overweighting sampling sites due to differences in sampling frequency. First, we calculated a sample CPUE value for each specific fish type (hatchery origin winter-run Chinook, wild origin winter-run Chinook, hatchery origin Steelhead, wild origin Steelhead, etc.) by dividing the total number of individuals caught by the total volume of water sampled, for each sample:

$$\begin{aligned}\text{Seine Sample Volume (m}^3\text{)} \\ &= \text{Seine Width (m)} \\ &\times \text{Seine Length (m)} \\ &\times \text{Seine Depth (m)} \times 0.5\end{aligned}$$

$$\begin{aligned}\text{Trawl Sample Volume (m}^3\text{)} \\ &= \text{Flow Meter Revolutions} \\ &\times 0.026873\text{(m/revolution)} \\ &\times \text{Net Mouth Area (m}^2\text{)}\end{aligned}$$

$$\text{Sample CPUE}_{\text{i}_\text{j}} = \frac{\text{Count}_{\text{i}_\text{j}}}{\text{Sample Volume (m}^3\text{)}}$$

where *i* indexes species and *j* indexes sites. We then averaged sample CPUE values by month within sampling sites:

$$\overline{\text{Monthly CPUE}_{\text{i}_\text{j}}} = \frac{\sum_{\text{Site:Month}} \text{Sample CPUE}_{\text{i}_\text{j}}}{\text{N}}$$

where *i* indexes species and *j* indexes sites. We then averaged the mean monthly CPUE values for sampling sites across their respective seine region or trawl site within each month, to obtain the mean monthly CPUE for each seine region and trawl site reported here:

$$\overline{\text{Monthly CPUE}_{\text{i}_\text{k}}} = \frac{\sum_{\text{Region:Month}} \overline{\text{Monthly CPUE}_{\text{i}_\text{j}}}}{\text{N}}$$

where *i* indexes species, *j* indexes sites, and *k* indexes seine regions or trawl sites. We calculated mean annual CPUE values for each seine region and trawl site by averaging monthly CPUE values for each seine region and trawl site across months, within each field year:

$$\overline{\text{Annual CPUE}_{\text{i}_\text{k}}} = \frac{\sum_{\text{Region:Field Year}} \overline{\text{Monthly CPUE}_{\text{i}_\text{k}}}}{\text{N}} \times 10{,}000$$

where *i* indexes species and *k* indexes seine regions or trawl sites.

Results and Discussion

Delta Immigration- Sacramento River Basin

In the 2019 field year, we detected winter-run sized juvenile Chinook Salmon entering the Delta from the Sacramento River Basin from November 29 to April 10. Their relative abundance as detected by the Lower Sacramento River and Delta entrance seines peaked in the months of December and January while the Delta entrance trawl relative abundance peaked in April (Figure 2). Winter-run hatchery releases occurred in the months of February and March (RMIS 2021) and were detected at the Delta entrance from February through April. We observed a higher proportion of hatchery fish caught in trawls compared to seines. This trend has been observed across multiple years in this region and is likely the result of body size and habitat use differences between hatchery origin and wild-stock fish. Specifically, salmonids in near-shore habitats sampled by seines are found to be smaller (wild origin), while larger, hatchery origin fish tend to reside in deep channel habitats sampled by trawls (Roegner et al. 2016).

Spring-, late fall-, and fall-run sized juvenile Chinook Salmon were detected from November 30 to July 24 during the 2019 field year. At seine sites, peak relative abundance was observed in January and February and trawl relative abundance peaked in April (Figure 2). The proportion of hatchery fish in trawl catches coincided with the timing and magnitude of hatchery releases, which occurred from the months of December through May (RMIS 2021).

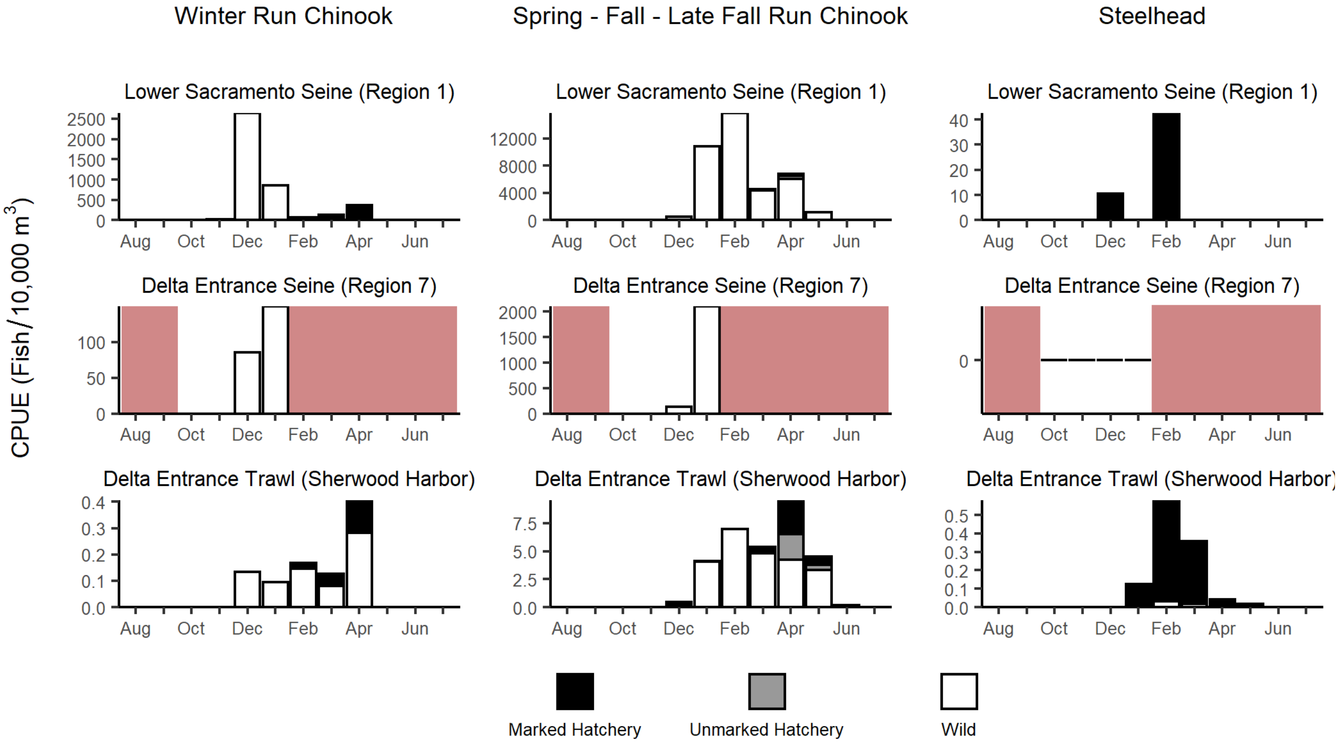

Figure 2: Timing of juvenile salmonids entering the Delta from the Sacramento River basin during the 2019 field year (August 2018 to July 2019). CPUE is catch-per-unit-effort. Different fish origins are denoted by different colors. Beach seine and trawl sites are located upstream of the Delta Cross Channel water diversion. The Sacramento River basin Delta entrance beach seine sampling occurred from October 1, 2018 to January 31, 2019 (red shading indicates periods without sampling). Note: the y-axis scales vary among species and sampling sites.

Juvenile Steelhead were detected from December 3 to May 28. Their relative abundance peaked in February for both the Lower Sacramento River seine sites and the Delta entrance trawl (Figure 2). Hatchery origin individuals made up 96.4% (165 of 171 individuals) of the juvenile Steelhead captured in this region. The six wild origin juvenile Steelhead were captured via mid-channel trawls as they entered the Delta from February to May. The scarcity of wild origin Steelhead in our catches from the Sacramento Basin highlight the relatively poor condition of wild Central Valley Steelhead populations within the region (NMFS 2016).

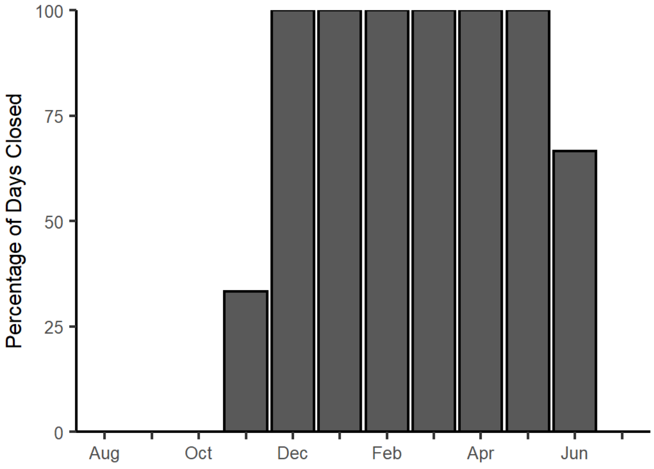

Figure 3: Delta Cross Channel operations as percentage of days closed per month during the 2019 field year (August 2018 to July 2019).

The full operation details of the Delta Cross Channel water diversion during the 2019 field year can be found in the annual reports of the Delta Operations for Salmonids and Sturgeon Technical Working Group (DOSS 2018; 2019). The overall timing and duration of DCC closures corresponded with our detection periods of juvenile salmonid in the region (Figures 2 and 3); suggesting that the DCC was closed during the period when a large number of juvenile salmonids

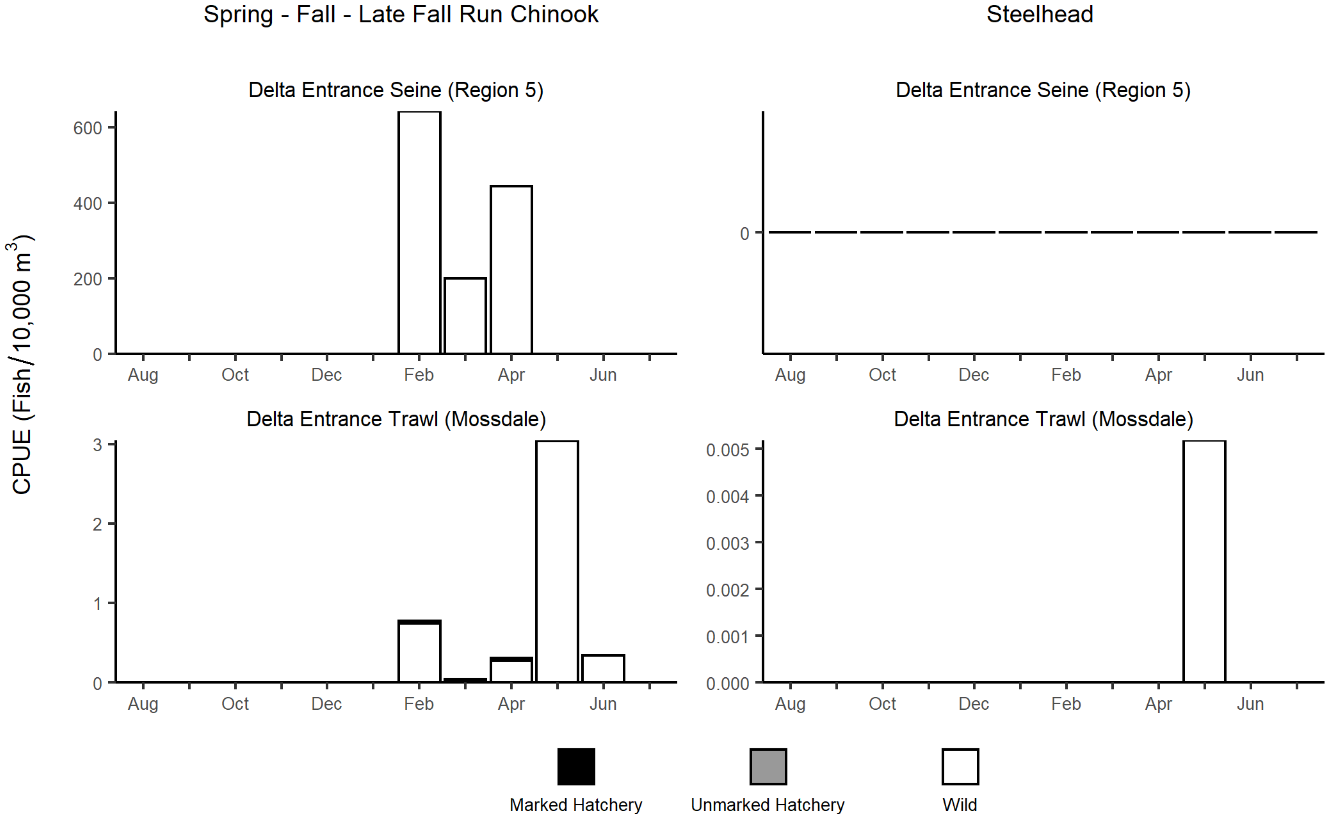

Figure 4: Timing of juvenile salmonid immigration into the Delta from the San Joaquin River basin during the 2019 field year (August 2018 to July 2019). CPUE is catch-per-unit-effort. Different fish origins are denoted by different colors. Delta entrance beach seine and trawl sites are located upstream of the head of Old River. Note: the y-axis scales vary among species and sampling sites.

were present, thereby reducing their risk of entrainment.

Delta Immigration- San Joaquin River Basin

At the San Joaquin River Delta entrance, we detected juvenile spring-, fall-, and late-fall sized juvenile Chinook Salmon entering the Delta from February 4 to June 26, with the peak relative abundance occurring in February (seines) and May (trawls) (Figure 4). Hatchery origin Chinook were detected exclusively by trawls from Feb 4 to May 24. The higher catch rate of hatchery Chinook in trawls is consistent with the trends seen at the Sacramento Delta entrance and juvenile hatchery Chinook behavior (Roegner et al. 2016). Hatchery spring-run Chinook originating from releases conducted by the San Joaquin River Restoration Program during the months of January and February were detected at the Delta entrance from February 4 to March 27.

Our Steelhead observations consisted of one wild-origin individual that was collected via trawl on May 6, 2019.

During the 2019 field year, installation of the spring fish barrier at the head of Old River was not attempted due to high flows on the San Joaquin River (DWR 2021). Therefore, a proportion of the juvenile salmonids entering the Delta from the San Joaquin River Basin likely used the Old River migratory corridor (Buchanan et al. 2013).

Delta Residency

We observed winter-run sized juvenile Chinook Salmon in the North Delta Region from December 4 to February 11, with a peak relative abundance occurring in the month of January (Figure 5). This was an increase in relative abundance compared to recent years and represented an 11-year high for the North Delta Region (Figure 6). We also observed winter-run sized juvenile Chinook Salmon in

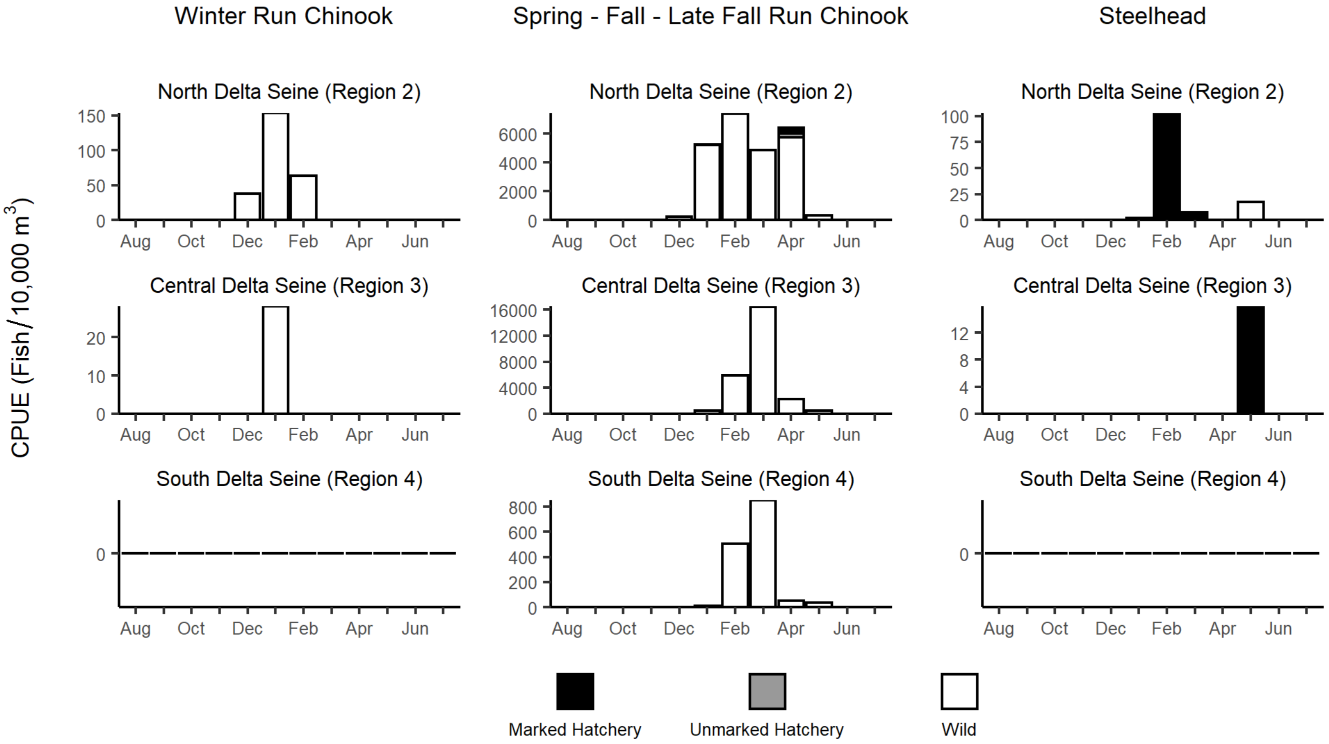

Figure 5: Timing of juvenile salmonid residency in littoral habitats of the Delta sampled by beach seines during the 2019 field year (August 2018 to July 2019). CPUE is catch-per-unit-effort. Different fish origins are denoted by different colors. Note: the y-axis scales vary among species and sampling sites.

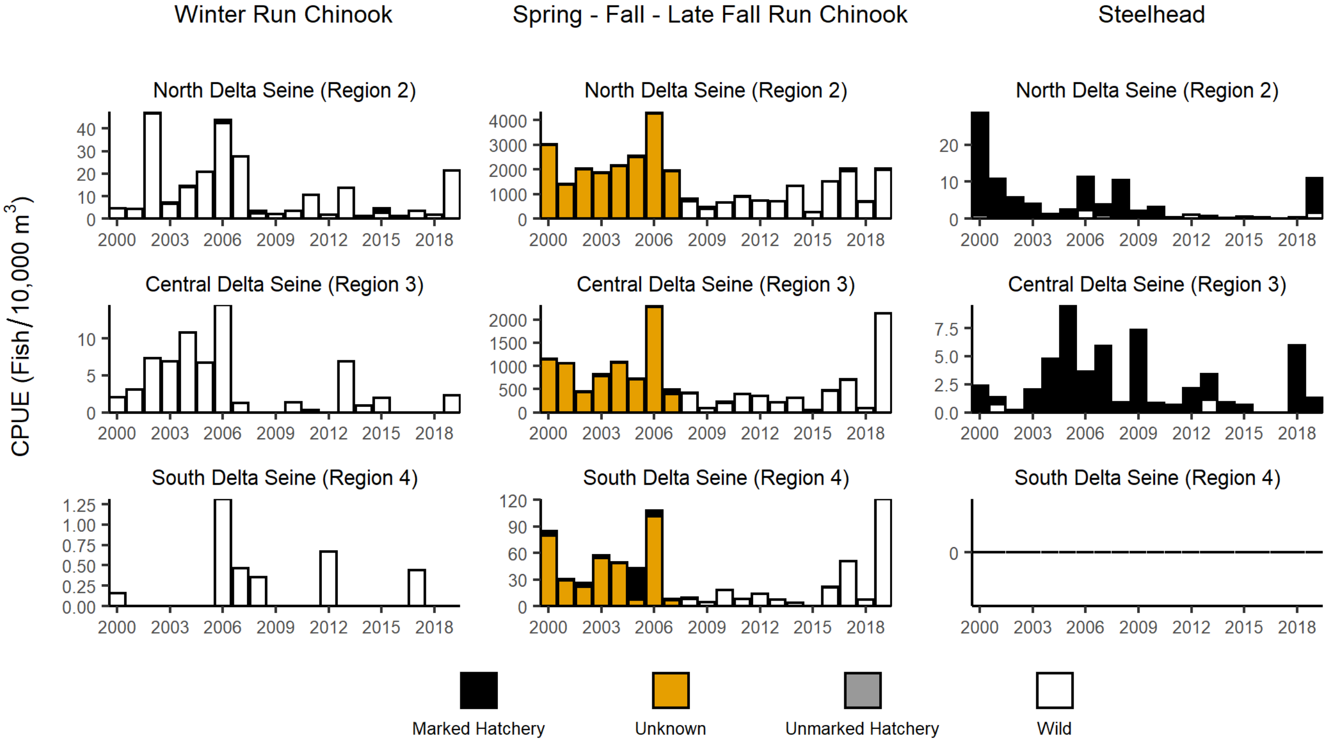

Figure 6: Annual catch-per-unit-effort (CPUE) of juvenile salmonids captured in littoral habitats of the Delta sampled by beach seines from 2000 to 2019. Different fish origins are denoted by different colors. Note: the y-axis scales vary among species and sampling sites.

the Central Delta in January. Given the DCC was closed during this period, our catches suggest that some proportion of juvenile winter-run Chinook Salmon likely used the Georgiana Slough migration corridor and may have been subject to lower survival rates in the interior Delta (Newman 2008; Newman and Brandes 2010). No winter-run Chinook Salmon were observed in the South Delta Region.

Spring-, fall-, and late-fall sized juvenile Chinook Salmon were observed in the North Delta Region in the 2019 field year from December 4 to June 12, with a peak relative abundance occurring in the month of February (Figure 5). In the Central Delta, these juvenile Chinook Salmon were observed from January 16 to May 21 and relative abundance was at a 13-year high and surpassed the relative abundance we observed for the North Delta (Figure 6). We also observed fall- and spring-run sized juvenile Chinook in the South Delta Region from January 18 to May 16 and relative abundance was the highest recorded for the region for the past 20 years (Figure 6). The high relative abundance we observed in 2019 in the Central and South Delta was likely correlated to the high fall-run adult Chinook Salmon returns observed on the Mokelumne River in the Fall of 2018 (CDFW 2020).

We observed a total of 19 juvenile Steelhead in the North Delta Region in the 2019 field year from January 25 to May 29. Hatchery origin individuals made up 84.2% (16 of 19 individuals) of the catch. In the North Delta Region, relative abundance was higher in the 2019 field year for both hatchery and wild origin Steelhead compared to recent years (Figure 6). One hatchery origin Steelhead was also detected in the Central Delta Region during May. No Steelhead were observed in the South Delta Region.

Delta Emigration

Winter-run sized juvenile Chinook Salmon exited the Delta between January 31 and

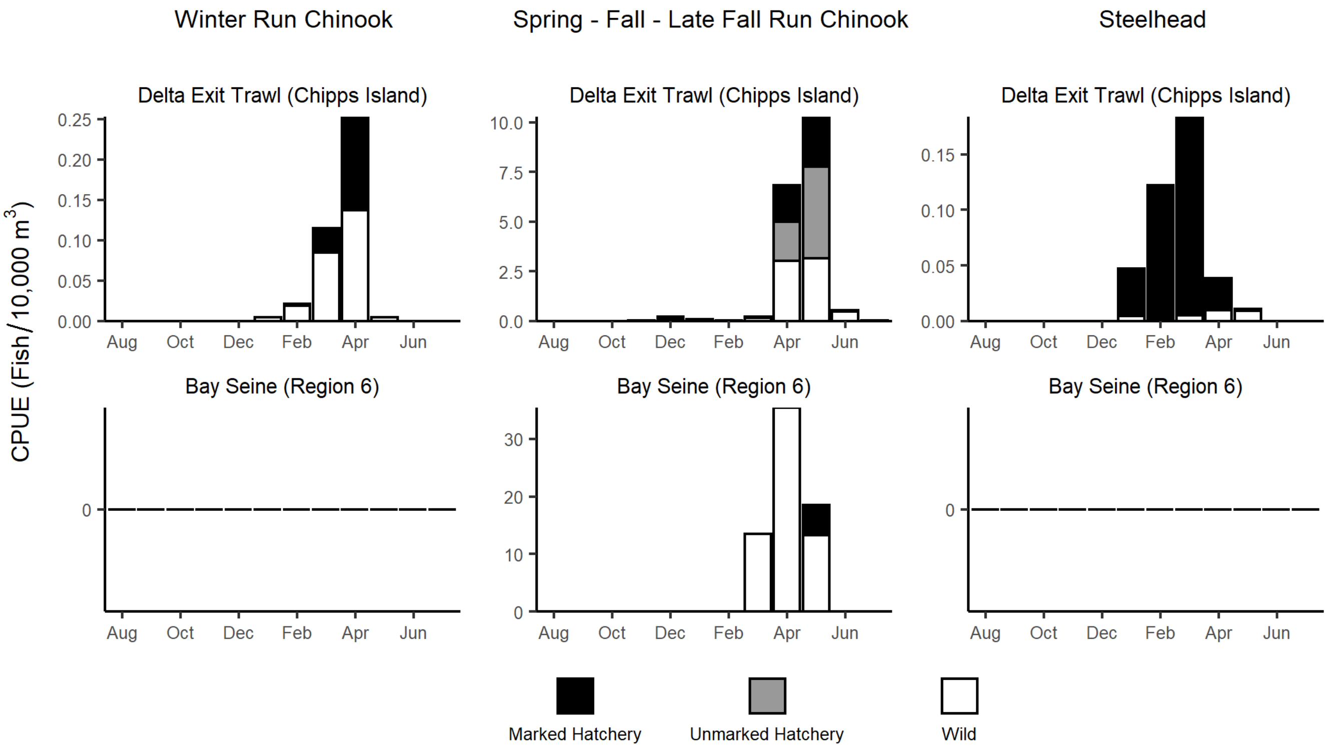

Figure 7: Timing of juvenile salmonid emigration from the Delta during the 2019 field year (August 2018 to July 2019). CPUE is catch-per-unit-effort. Different fish origins are denoted by different colors. Note: the y-axis scales vary among species and sampling sites.

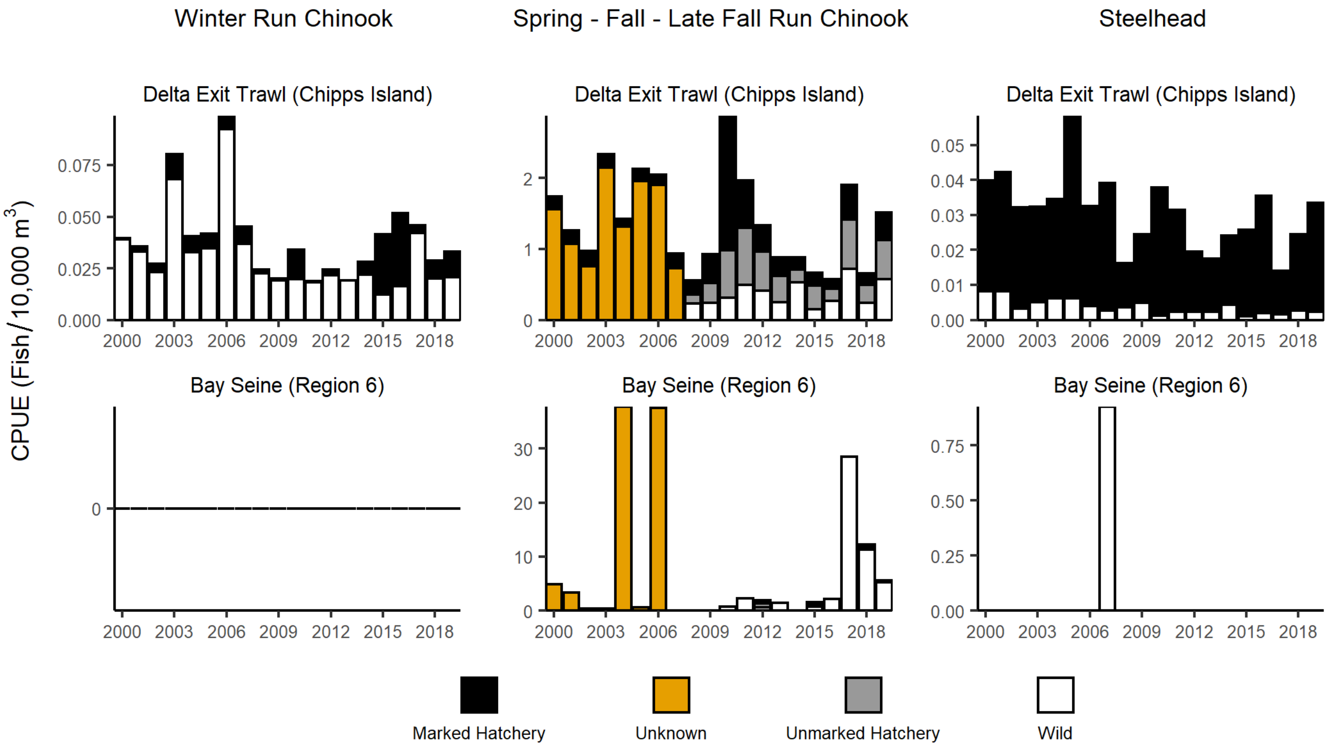

Figure 8: Annual catch-per-unit-effort (CPUE) of juvenile salmonids emigrating the Delta from 2000 to 2019. Different fish origins are denoted by different colors. Note: the y-axis scales vary among species and sampling sites.

May 20, with peak emigration occurring in the month of April (Figure 7). The relative abundance of wild origin winter-run sized Chinook exiting the Delta was similar to the past 11 years, excluding the high abundance we observed in the 2017 field year (Figure 8). No winter-run Chinook Salmon were detected in the Bay region seines.

Spring-, fall-, and late fall-run sized juvenile Chinook Salmon emigrated from the Delta between October 1 and July 24, with peak emigration occurring in the month of May. From October to March, the relative abundance was low and primarily consisted of hatchery origin fish (Figure 7). Wild origin fish were not common in catches until April. The earlier emigration of hatchery origin juveniles was likely due to a combination of factors that affected their residency time within the Delta, including the relative size and maturation state of individuals and the timing and location of their release (Pearcy et al. 1989). The relative abundance of wild origin juveniles exiting the Delta in the 2019 field year was the second highest since we began our estimates in 2008 (Figure 8). We also observed these juvenile Chinook in our Bay Seine from March 19 to May 20, which indicated that fry- and parr-sized juveniles emigrated from the Delta and contributed additional migratory phenotypes to the overall Central Valley Chinook Salmon cohort in the 2019 field year (Figure 7). This was the third year in a row that we have recorded a high relative abundance of these juveniles in the Bay (Figure 8). The high relative abundance and diverse migratory phenotypes we observed in the 2019 field year were positive indicators for recruitment in future years (Miller et al. 2010).

Juvenile Steelhead exited the Delta between January 14 and May 14, with peak emigration occurring in the month of March (Figure 7). Our total catch for the year was dominated by hatchery origin fish (130 of 141 individuals or 92.2%) and the low relative abundance of wild origin fish fell within the general range we have observed for the past 10 years (Figure 8). No Steelhead were detected in the Bay region seines in the 2019 field year.

Management Implications

Since 1976, the U.S. Fish and Wildlife Service’s Delta Juvenile Fish Monitoring Program (DJFMP) has monitored the annual timing, distribution, and relative abundance of juvenile salmonids throughout the Delta to better our understanding, inform the management, and mitigate the impacts of the CVP and SWP water export operations on salmonid populations. The data collected by the survey allows resource managers and researchers to track changes in the distribution and relative abundance of salmonid populations across time and space, and environmental conditions and management activities. Therefore, the DJFMP salmonid survey remains a critical component of fish management and conservation within the Delta. The full DJFMP dataset, including environmental data not included in this report and a description of sampling procedures are available at DJFMP’s Environmental Data Initiative Data Portal (IEP et al. 2020).

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2018-2019 Yolo Bypass Fisheries Monitoring Status and Trends Report

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Introduction

The California Department of Water Resources (DWR) has operated the Yolo Bypass Fish Monitoring Program (YBFMP), largely supported by the Interagency Ecological Program (IEP), since 1998. The program collects baseline data on hydrology, water quality, lower trophic metrics (phytoplankton, zooplankton, aquatic and terrestrial insects), and juvenile and adult fishes. The YBFMP, mandated under DWR's 2020 Incidental Take Permit (Section 3.13.1, CDFW 2020), has provided critical information regarding the significance of seasonal floodplain habitat to native fishes (Sommer et al. 2004a). As the largest remnant floodplain of the Sacramento River, the Yolo Bypass has been identified as a high restoration priority by the National Marine Fisheries Service's Biological Opinion (NMFS 2019), California EcoRestore (CDWR 2021a), and the California Natural Resources Agency Delta Smelt (CNRA 2016) and salmon resiliency strategies (CNRA 2017). As such, the baseline data provided by the YBFMP are critical for evaluating the success of current and future restoration projects. Moreover, for over two decades, data acquired from this monitoring effort have increased our understanding of the crucial role that the Yolo Bypass plays in the San Francisco Estuary ecosystem (e.g., Sommer et al. 1997; Sommer et al. 2001; Feyrer et al. 2006a; Lehman et al. 2007; Frantzich et al. 2018; Goertler et al. 2018; Mahardja et al. 2019). This report describes the fisheries sampling effort for water year (WY) 2019 (October 1, 2018 – September 30, 2019), including a summary of water quality metrics and fish catch by species and gear type.

We also highlight in this report the role of the YBFMP high flow beach seine sites. In WY 2019, the Yolo Bypass maintained varying levels of inundation for a total of 73 days from February 16th to April 19th. We investigated species composition and catch per volume seined (CVP) among these high flow sites as well as the core sites, asking: did the increase in spatial scope in 2019 allow us to better monitor use of the floodplain by different fish species? To answer this question, we compared high flow sites with core sites, looking at beach seine data only during inundation periods.

Methods

Study Site

Sampling occurred in the Toe Drain, a perennial riparian channel on the eastern edge of the Yolo Bypass (Figure 1). The 2019 water year was characterized as "wet" according to the California Data Exchange Center's Water Supply Index (CDWR 2021b).

Water Quality

Field crews concurrently collected several discrete water quality parameters using a YSI Pro DSS handheld instrument and Secchi disc during each fish sampling event, which occur weekdays October – June and once every other week in the summer. These parameters included: water temperature (°C), specific conductivity (µS/cm), dissolved oxygen (mg/L), pH, turbidity (FNU), and Secchi depth (m). Additionally, a multi-parameter YSI 6600 Sonde (Yellow Springs Instruments) located at Lisbon Weir and a YSI EXO2 Sonde at Hood, CA on the Sacramento River collected dissolved oxygen, turbidity, conductivity, pH, temperature, and chlorophyll-a (µg/L) at 15-minute intervals year-round.

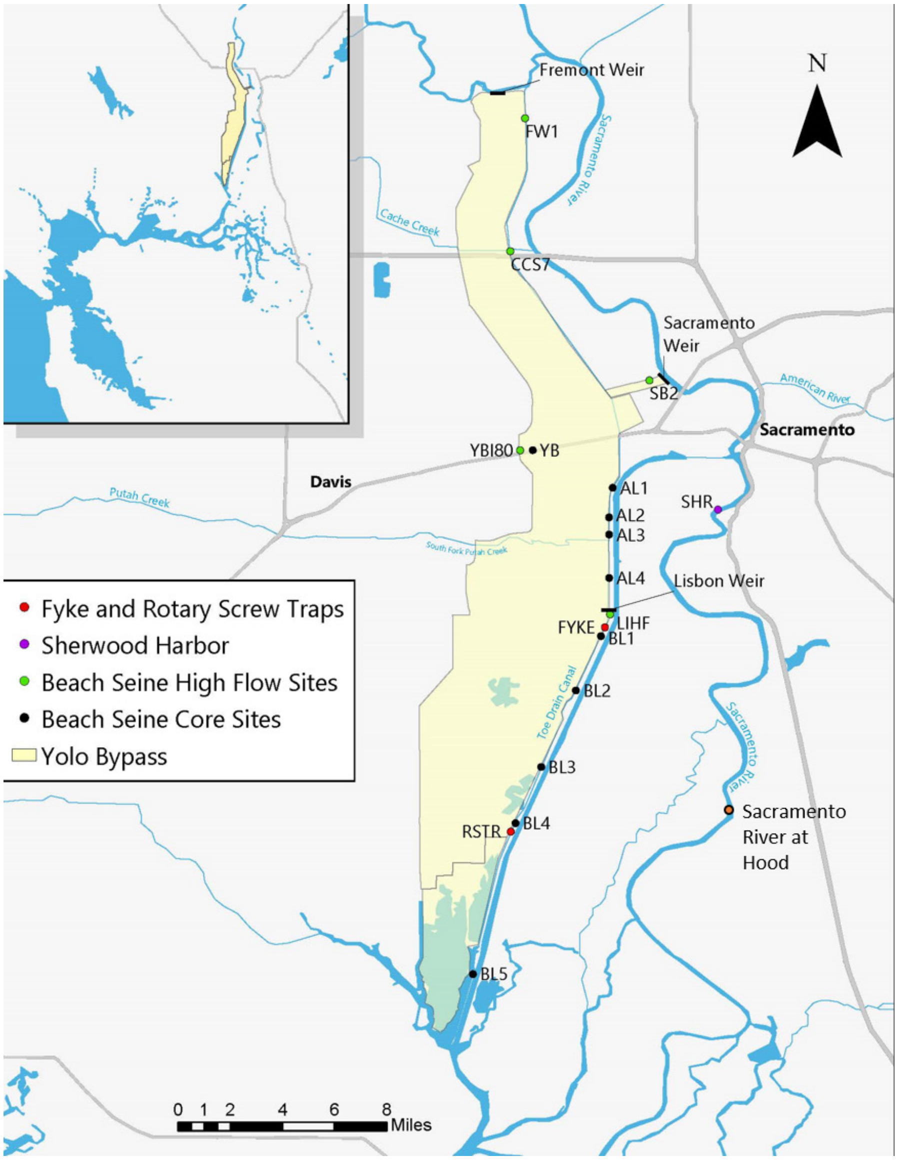

Figure 1. Map of Yolo Bypass within the San Francisco Estuary showing the various sampling locations of the Yolo Bypass Fish Monitoring Program.

Larval Fishes

A survey for the general composition and timing of larval fishes in the Toe Drain has been conducted since 1999. Sampling is conducted by towing a 2 m long, 500 µm mesh net with a 0.65 m diameter opening for 10 minutes during ebb tide. A single tow is taken every other week between January and June at the rotary screw trap location (Figure 1).

Juvenile and Adult Fishes

Small adult (e.g. Delta Smelt) and juvenile fish have been sampled with a 2.44m diameter rotary screw trap (RSTR) located in the Toe Drain of the Yolo Bypass approximately 14.5km south of the Lisbon Weir (Figure 1) since 1998 for up to seven days a week during the months of January – June (Figure 2). The rotary screw trap generally operates five days a week from January – June and the sampling time (total hours based on set, check, and pull times) is used to calculate catch per hour as the volume of water sampled is unknown. Circumstances that prevent fishing the trap a full five days per week include obstruction by large debris or strategic avoidance of high debris flow periods.

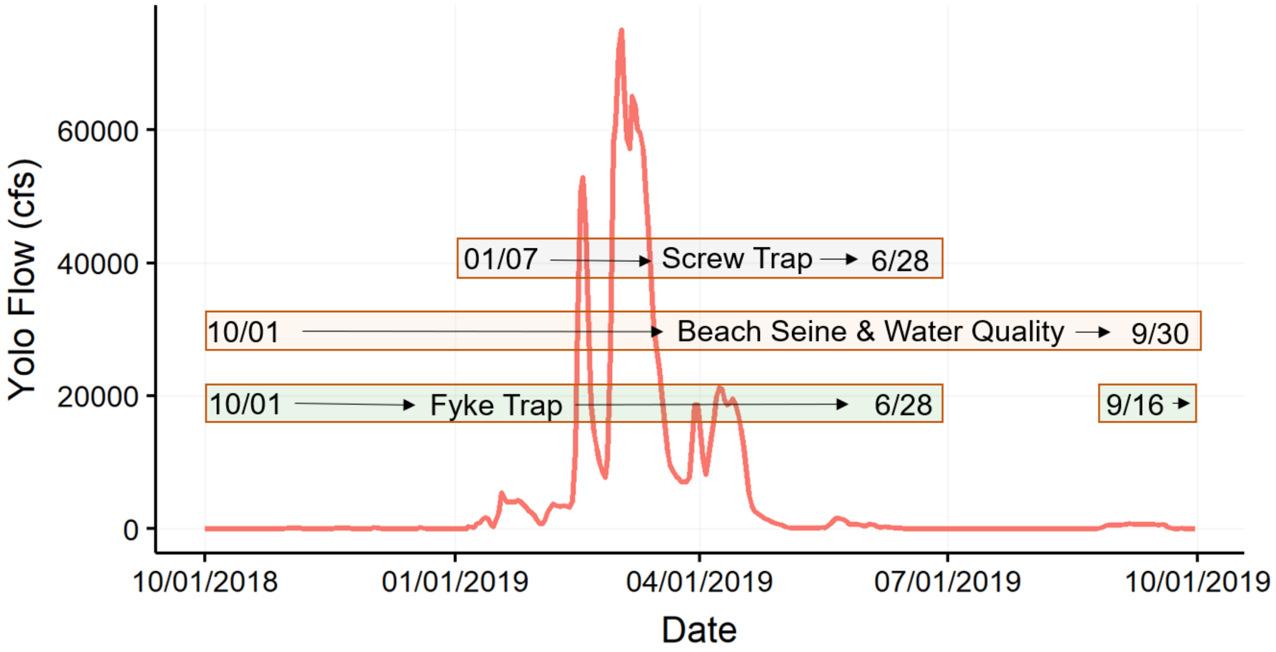

Figure 2. Water year 2019 average daily flow at Lisbon Weir (Yolo Bypass, CA) overlaid with Yolo Bypass Fish Monitoring Program sampling periods by gear type (CDWR 2019a, Yolo Dayflow).

Every other week throughout the year, we supplement the collection of small adult and juvenile fish in the Yolo Bypass by conducting beach seine surveys at various locations along the Toe Drain (Figure 1, 2). A 7.6 m wide and 1.2 m tall seine net with 0.32 cm mesh was used. The spread of Water Hyacinth (*Eichhornia crassipes*) in the Toe Drain occasionally precluded beach seine sampling at station BL5. During periods of inundation, we sampled an additional 5 sites that are only accessible during flooding.

The YBFMP has seasonally deployed a 3.15 m diameter steel-framed fyke trap since 1999 to monitor upstream migrations of large adult fish in the Toe Drain. The fyke trap is operated five days a week during the months of October – June (Figure 1, 2) and is checked once every 24 hours. The trap is located 1.2 km below Lisbon Weir and 21 km north of the terminus of the Toe Drain (Figure 1). Data for all fish and lower trophic organism catch, along with associated water quality data, can be accessed online as part of the Environmental Data Initiative (IEP 2019; IEP 2020). For all methods, proportion of catch was calculated using the following equation:

$$x = \left(\frac{total\ count\ of specific\ species\ by\ gear\ type}{total\ count\ of\ all\ species\ by\ gear\ type}\right) \times 100$$

Results and Discussion

Hydrology

The Sacramento River watershed experienced a wet year of precipitation during WY 2019 (CDWR 2020b). The Yolo Bypass had an average daily flow of 5,254 cfs, with a peak flow of 75,000 cfs on March 3rd, 2019 (Figure 1, CDWR 2020c); over three times lower than the peak flow of WY2017, which was also a wet year (Kwan et al. 2019). Flooding events occur when the water levels at Fremont Weir and Lisbon Weir exceed their monitoring stage heights (32 and 13 feet, respectively) and spill into

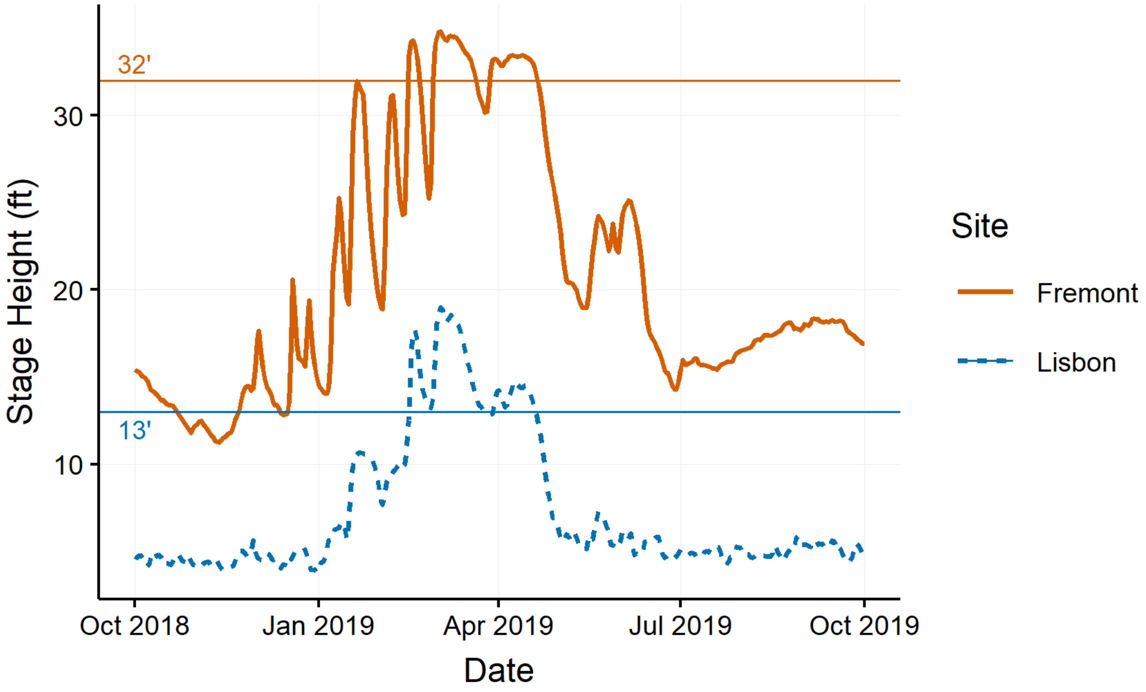

Figure 3. Stage heights (ft) of Lisbon and Fremont Weir and corresponding inundation thresholds. Fremont Weir is located at the northern end of the Yolo Bypass within the San Francisco Estuary. Lisbon Weir is located in the Toe Drain channel, which runs along the eastern side of the bypass.

the Yolo Bypass. Historically, the Yolo Bypass floods two out of three years (Schemel et al. 2004). WY 2019 was the second largest flood in the past decade, surpassed only by WY2017. Throughout WY 2019, Fremont Weir overtopped for a total of 52 days across four time periods (CDWR 2020a; Figure 3). Fremont Weir overtopped briefly from January 20th – 21st, then February 15th – 20th, and for a longer period from February 28th – March 20th, and March 28th – April 20th, with a maximum stage height of 34.82 m (Figure 3). Lisbon Weir overtopped for 58 days from February 16th – March 24th and March 30th – April 19th, with a maximum stage height of 18.99 m (Figure 3). As a result, the bypass remained inundated, with varying levels of spatial extent, for 73 days from February 16th – April 19th. Inundation events are important to the aquatic habitats and resident fish populations of the Yolo Bypass as they drive food web production and provide spawning and rearing habitat for native fish species (Harrell and Sommer 2003; Kwan et al. 2019) such as the Chinook Salmon (*Oncorphynchus tshawytscha*; Takata et al. 2017), Sacramento Splittail (*Pogonichthys macrolepidotus*), Sacramento Blackfish (*Orthodon microlepidotus*), and Delta Smelt (*Hypomesus transpacificus*).

Water Quality

In WY 2019, conductivity in the Yolo Bypass (113.4 - 823.8 µS/cm) was far more variable than in the Sacramento River (84.49 - 226.84 µS/cm; Figure 4A). The extreme variability in the bypass can be attributed to its unique hydrologic complexity, as conductivity is a key indicator of significant changes in water source input and water chemistry (Schemel et. al. 2004). This complexity is affected by tidal flow, residence time, salinity, and sediment transportation/deposition (Frantzich et. al. 2018). The Yolo Bypass is hydrologically complex as it receives water from several sources including adjacent tributaries, agricultural drainage, seasonal flooding, and tidal flows, which also contribute to conductivity fluctuations (Sommer et al. 2004b). The lowest conductivity measurements in the Yolo Bypass coincided with the observed spikes in daily flow. Conversely, the highest conductivity measurements were observed during the early-summer and late-fall seasons, when there is little to no water entering the system from upstream sources and water temperatures are high.

Turbidity can be an essential part to the health and function of an estuarine habitat as it determines the depth of the euphotic zone, which is the area where primary production can establish and help create valuable pelagic fish habitat (Morgan-king and Schoellhamer 2013; Frantzich et al. 2018). Turbidity in the Yolo Bypass is typically higher and more variable than in the Sacramento

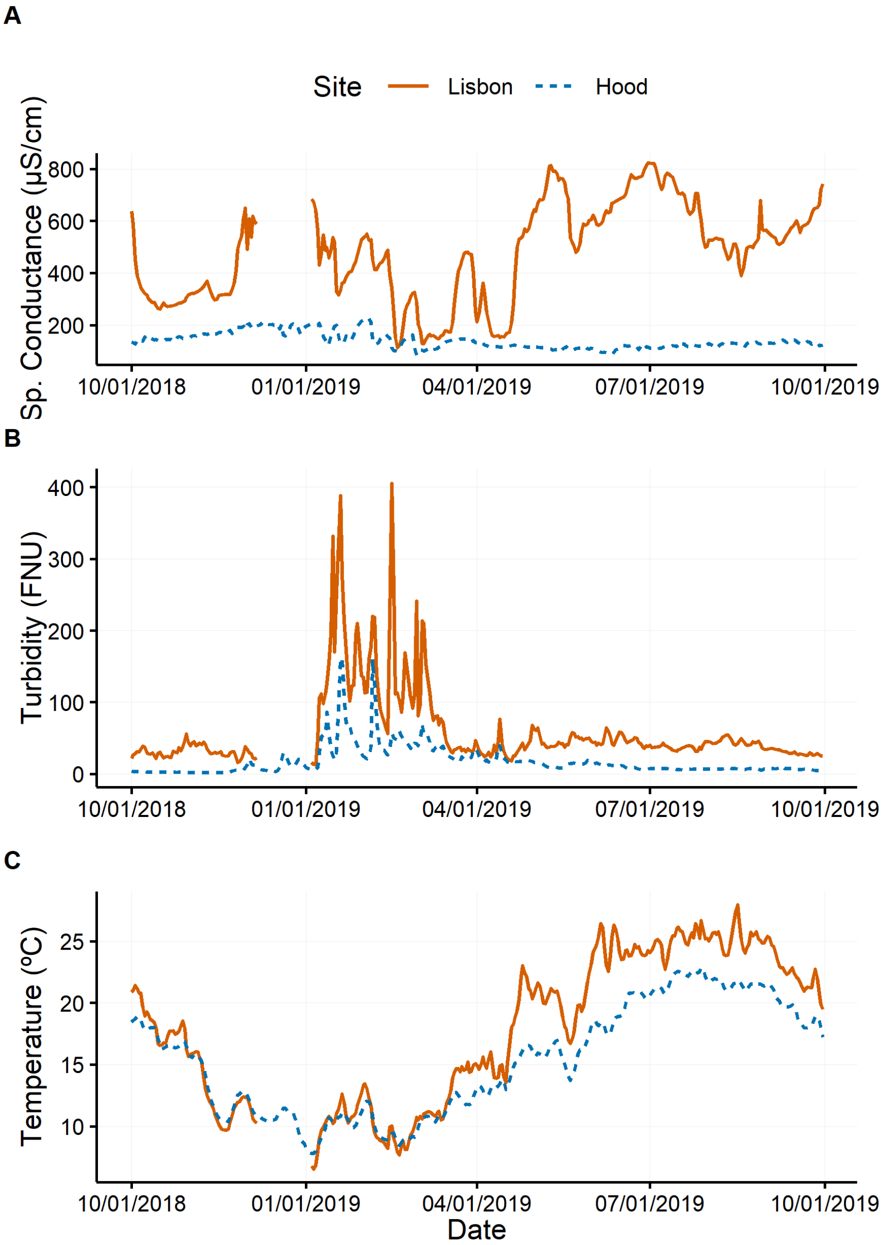

Figure 4. A. Turbidity (FNU), B. specific conductivity (µS/cm), and C. water temperature (°C) during water year 2019 at Lisbon Weir in the Yolo Bypass and Hood Station in the Sacramento River.

Table 1. Catch summary from the water year 2019 larval fish sampling at the Yolo Bypass rotary screw trap site, sorted by date and listed in descending order of count. Each sample represents a single tow from the middle portion of the Yolo Bypass Toe Drain.

Common Name	Scientific Name	22-Jan	5-Feb	19-Feb	26-Feb	11-Mar	20-Mar	28-Mar	3-Apr	8-Apr	15-Apr	22-Apr	6-May	20-May	3-Jun	17-Jun	1-Jul	15-Jul	Total
Unidentified juvenile minnow	*Cyprinidae*	0	0	0	0	0	0	6	27	4	9	0	3	1	0	0	0	0	50
Prickly Sculpin	*Cottus asper*	0	4	0	2	0	0	4	5	0	8	0	3	0	0	0	0	0	26
American Shad	*Alosa sapidissima*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	2	1	14
Bigscale Logperch	*Percina macrolepida*	0	0	0	0	0	0	2	0	0	1	1	0	0	0	0	0	0	4
Inland Silverside	*Menidia beryllina*	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	4
Common Carp	*Cyprinus carpio*	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
Unidentified Crappie	*Pomoxis* sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

River. However, during the winter months of WY 2019, two notable spikes in turbidity occurred concurrently in the Bypass and the Sacramento River (Figure 4B). The first major increase in turbidity is usually a product of sediments dislodged and/or mobilized from the first big winter storm, while subsequent increases are often associated with heavy rainstorms that transport large pulses of sediment through the watershed (Morgan-King and Schoellhamer 2013). The highest turbidity recorded in the Yolo Bypass during WY 2019 was 405 FNU compared to 161 FNU in the Sacramento River.

Water temperatures in the Yolo Bypass are generally higher but more variable than in the Sacramento River (Goertler et al. 2018). Although both locations follow typical seasonal trends with peak temperatures in the summer and coolest temperatures in the winter. The shallow and broad topography of the inundated Yolo Bypass floodplain results in more extreme hydrologic variability throughout the year (Sommer et al. 2004a). In WY 2019, for example, the highest water temperature in the Yolo Bypass at Lisbon Weir occurred on August 16th, 2019, at 27.96 °C, while the Sacramento River at Hood (henceforth: Sacramento River; Figure 1) peaked at 22.84 °C on July 28, 2019 (Figure 4C). The lowest water temperature recorded in the bypass and Sacramento River was 6.54 °C and 7.79°C, respectively. Water temperature plays a significant role not only for lower trophic food production (Lehman et al. 2007) but also for the timing of outmigration from the floodplain (Takata et. al. 2017) and increased size diversity of juvenile Chinook Salmon (Goertler et al. 2018).

Fishes

In WY 2019, the greatest larval fish species by count was Threadfin Shad (*Dorosoma petenense*; 41%; Table 1). Over 75% of the Threadfin Shad observed were sampled on June 3rd, 2019. Threadfin Shad spawning occurs around floating or partially submerged objects such as logs, brush, or aquatic plants and occurs from April through August, with peaks in June and July when water temperatures exceed 20°C (Moyle 2002). Water temperatures in the Yolo Bypass

Table 2. Fish species catch data summarized by gear type for WY2019, sorted in descending order of total abundance. Proportion (species catch/overall catch) by gear method is included in parentheses.

Common Name	Scientific Name	Screw Trap Catch	Screw Trap Percent	Fyke Catch	Fyke Percent	Beach Seine Catch	Beach Seine Percent	Total
Splittail	*Pogonichthys macrolepidotus*	23645	79.13%	310	5.49%	536	4.12%	24491
Inland Silverside	*Menidia beryllina*	3137	10.50%	62	1.10%	6408	49.30%	9607
White Catfish	*Ameiurus catus*	10	0.03%	4133	73.23%	3	0.02%	4146
Threadfin Shad	*Dorosoma petenense*	216	0.72%	4	0.07%	1879	14.45%	2099
Black Crappie	*Pomoxis nigromaculatus*	1189	3.98%	218	3.86%	614	4.72%	2021
Bigscale Logperch	*Percina macrolepida*	0	0.00%	0	0.00%	1107	8.52%	1107
Western Mosquitofish	*Gambusia affinis*	381	1.27%	0	0.00%	626	4.82%	1007
Bluegill	*Lepomis macrochirus*	14	0.05%	17	0.30%	847	6.52%	878
Chinook Salmon	*Oncorhynchus tshawytscha*	447	1.50%	27	0.48%	164	1.26%	638
Striped Bass	*Morone saxatilis*	3	0.01%	407	7.21%	8	0.06%	418
Largemouth Bass	*Micropterus salmoides*	183	0.61%	0	0.00%	138	1.06%	321
Golder Shiner	*Notemigonus crysoleucas*	172	0.58%	1	0.02%	92	0.71%	265
Sacramento Blackfish	*Orthodon microlepidotus*	180	0.60%	0	0.00%	28	0.22%	208
Channel Catfish	*Ictalurus punctatus*	2	0.01%	179	3.17%	12	0.09%	193
Common Carp	*Cyprinus carpio*	16	0.05%	96	1.70%	67	0.52%	179
Redear Sunfish	*Lepomis microlophus*	16	0.05%	10	0.18%	134	1.03%	160
Fathead Minnow	*Pimephales promelas*	4	0.01%	0	0.00%	125	0.96%	129
Sacramento Sucker	*Catostomus occidentalis*	28	0.09%	59	1.05%	32	0.25%	119
American Shad	*Alosa sapidissima*	87	0.29%	21	0.37%	8	0.06%	116

Common Name	**Scientific Name**	**Screw Trap Catch**	**Screw Trap Percent**	**Fyke Catch**	**Fyke Percent**	**Beach Seine Catch**	**Beach Seine Percent**	**Total**
Lamprey	Petromyzontidae	63	0.21%	0	0.00%	0	0.00%	63
Black Bullhead	*Ameiurus melas*	3	0.01%	49	0.87%	4	0.03%	56
Hitch	*Lavinia exilicauda*	8	0.03%	1	0.02%	46	0.35%	55
Sacramento Pikeminnow	*Ptychocheilus grandis*	13	0.04%	17	0.30%	25	0.19%	55
Prickly Sculpin	*Cottus asper*	15	0.05%	0	0.00%	34	0.26%	49
Shimofuri Goby	*Tridentiger bifasciatus*	26	0.09%	0	0.00%	9	0.07%	35
Brown Bullhead	*Ameiurus nebulosus*	0	0.00%	22	0.39%	1	0.01%	23
Warmouth	*Lepomis gulosus*	1	0.00%	1	0.02%	15	0.12%	17
Tule Perch	*Hysterocarpus traskii*	0	0.00%	1	0.02%	12	0.09%	13
Wakasagi	*Hypomesus nipponensis*	6	0.02%	0	0.00%	6	0.05%	12
Rainwater Killifish	*Lucania parva*	3	0.01%	0	0.00%	7	0.05%	10
Goldfish	*Carassius auratus*	4	0.01%	2	0.04%	2	0.02%	8
Rainbow Trout (Steelhead)	*Oncorhynchus mykiss*	5	0.02%	2	0.04%	0	0.00%	7
White Crappie	*Pomoxis annularis*	1	0.00%	3	0.05%	3	0.02%	7
Green Sunfish	*Lepomis cyanellus*	0	0.00%	0	0.00%	6	0.05%	6
Threespine Stickleback	*Gasterosteus aculeatus*	4	0.01%	0	0.00%	0	0.00%	4
White Sturgeon	*Acipenser transmontanus*	0	0.00%	2	0.04%	0	0.00%	2
Spotted Bass	*Micropterus punctulatus*	0	0.00%	0	0.00%	1	0.01%	1
Yellowfin Goby	*Acanthogobius flavimanus*	1	0.00%	0	0.00%	0	0.00%	1

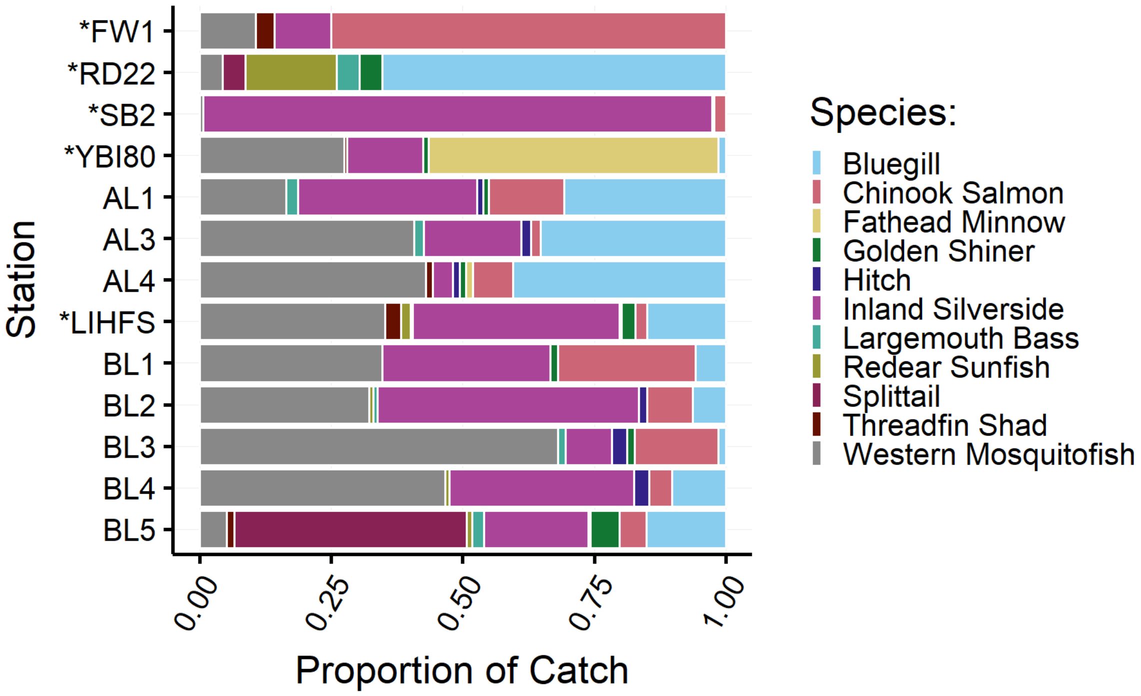

Figure 5. Species proportion based on catch per volume seined at sampling stations shown from north (top) to south (bottom). The asterisk indicates high flow sites.

where and when the sample was collected ranged from 20.7°C to 22.3°C the week prior to sampling, creating prime spawning habitat for Threadfin Shad. Of the total amount of larval fish sampled, 0.58% were classified as Unidentified Crappie and 29.1% were Unidentified Minnow species (too small to speciate; Table 1).

A total of 38 fish species were collected in WY 2019; 11 of which are native to the Sacramento-San Joaquin River Delta (Table 2). The native Sacramento Splittail was the greatest species by count in the rotary screw trap (79.13%). Splittail are floodplain-associated species that frequent the Yolo Bypass and spawn between the months of January and May, depending on available floodplain habitat (Feyrer et al. 2006b). A large portion (17,241 fish or 72.9%) of the juvenile Splittail sampled using the rotary screw trap were captured in May. This is not surprising considering the Yolo Bypass was inundated from mid-January through April, providing good habitat for spawning (Moyle 2002).

Inland Silverside (*Menidia beryllina*) were the greatest species by count using the beach seine sampling method (49.3%) and White Catfish (*Ameiurus catus*) were the greatest species by count using the fyke trap sampling method (73.23%). Both these species are nonnative to the Yolo Bypass.

WY 2019 Highlight: Inundation Period Beach Seine Site Comparison

When the Sacramento River overtops the Fremont Weir it allows water to inundate the Yolo Bypass. Given the importance of floodplain connection and inundation for fish rearing and spawning (Sommer et al. 2001), the YBFMP increases beach seine sampling during these events to better capture the response of resident and migrant fish species, especially that of native species. Specifically, the YBFMP field crew conducts seines weekly instead of every other week and visits an additional 5 sites. Four of these sites are upstream of the core sites while one is located near Lisbon Weir (Figure 1). All these additional sites, termed “high flow

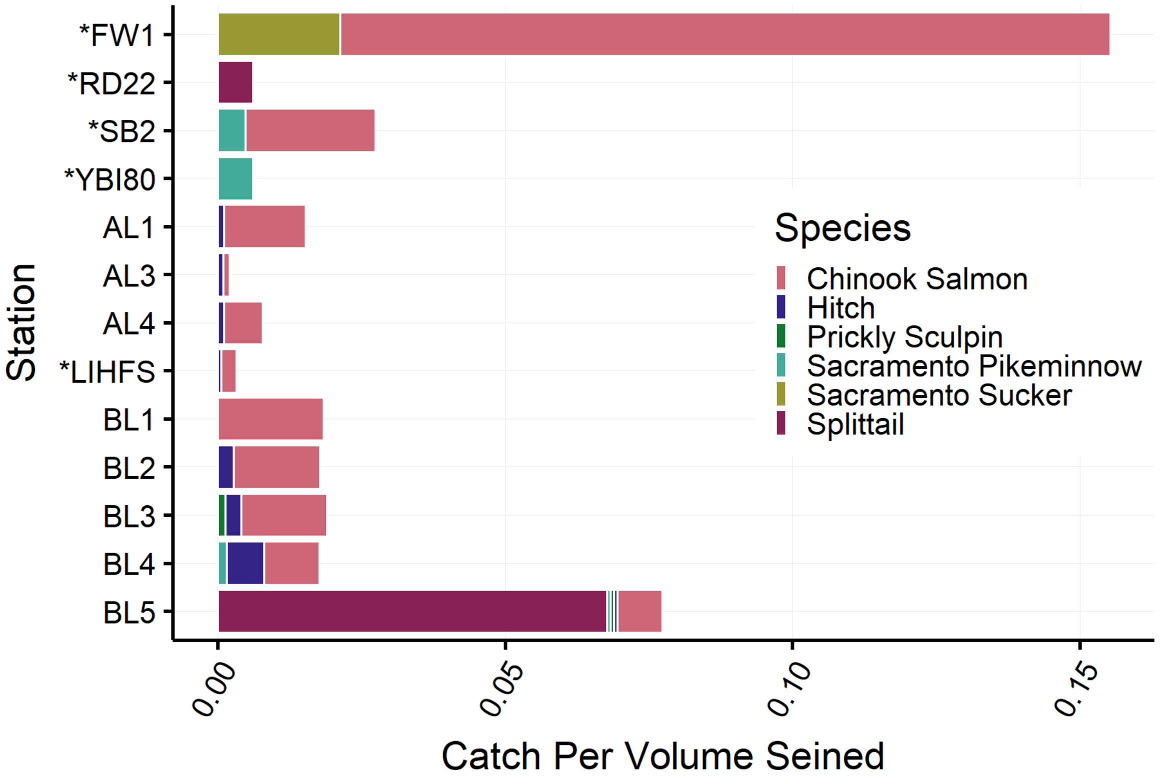

Figure 6. Native fishes catch per volume seined sampled at sampling stations shown from north (top) to south (bottom). The asterisk indicates high flow sites.

sites" are only accessible during periods of bypass inundation, otherwise they remain dry. We plotted species composition and CPV among these high flow and core sites during periods of inundation to better understand how these additional high flow sites relate to our core monitoring sites. We removed rare species caught <0.5% of the time to ease interpretation of colors on the plots.

We observed, through exploratory plotting, differences in species proportion of catch by count among the high flow sites (Figure 5). Just south of the Fremont Weir at site FW1 (Figure 1), Chinook Salmon made up 75% of catch. Additionally, RD22 showed a higher percentage of Bluegill (*Lepomis macrochirus*; 68%) and Redear Sunfish (*Lepomis microlophus*; 18%) than all other sites. Catch at SB2 was comprised of 97% Inland Silverside while YBI80 had the highest percentage of Fathead Minnow (*Pimephales promelas*) catch, at 55%. Unlike the other high flow sites, LIHFS's species composition was more similar to the core sites which border it to the north and south. Relative to the high flow sites, the core sites showed a more consistent pattern of species composition, with Western Mosquito Fish (*Gambusia affinis*), Inland Silverside, and Bluegill dominating the catch. However, BL5, the southernmost site, differed from this trend, with Sacramento Splittail comprising 42% of catch during the inundation period.

We also saw differences in CPV of native species among the high flow sites (Figure 6). FW1, the northern most site, had the highest CPV of Chinook Salmon of all sites sampled. FW1 also had the highest CPV of native fishes including the highest CPV of Sacramento Sucker (*Catostomus occidentalis*). Chinook Salmon were caught at all monitoring sites during the inundation period of WY 2019 except RD22 and YBI80. YBI80, however, had the highest CPV of

Sacramento Pikeminnow (*Ptychocheilus grandis*) overall and RD22 the highest CPV of Sacramento Splittail among the high flow sites. Core sites below Lisbon Weir (‘BL’ sites) generally had higher CPV of native species compared to core sites above Lisbon Weir (‘AL’ sites), which corresponds to similar trends during non-inundation periods (Kwan et al. in press). LIHFS and AL3 had the lowest CPV of native species. BL5 had the second highest CPV of native species overall and the highest CPV of Sacramento Splittail in the inundation period of WY 2019.

In conclusion, increasing the spatial scope of monitoring during periods of inundation in WY 2019 provided valuable information. The high flow sites sampled had varied species composition and resulted in catch of native species. FW1 proved to be an important monitoring site for WY 2019 because of its high CPV of Chinook Salmon and Sacramento Sucker. In contrast, LIHFS provided less benefit as it had a comparatively low CPV of native species and a similar composition of species to other core sites. Further analysis is needed to determine whether this pattern persists across sites during other water years in which inundation occurred.

Summary

WY 2019 included the second largest inundation event in the past decade. Peak turbidity, electrical conductivity, and water temperature were higher in the Yolo Bypass than in the Sacramento River reference site. Larval tows caught more Threadfin shad than any other fish species. Sacramento Splittail made up the highest proportion of fish catch in rotary screw trap, Inland Silverside made up the highest proportion of catch in beach seining, and White Catfish made up the highest proportion of catch in the fyke trap. Sacramento Splittail made up the highest proportion of native species catch and were captured across all sampling methods.
Our evaluation of species composition and catch per volume seined between our high flow and core beach seine sites highlighted that species composition is quite variable between high flow and core seine sites as well as among the different high flow sites. Additionally, salmon catch for WY 2019 was highest at our northernmost seining site, FW1. Overall, WY 2019 provides a valuable flood year data for future large-scale Yolo Bypass analyses.

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2019 Phytoplankton Status and Trends Report

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Introduction

The Department of Water Resources (DWR) and the US Bureau of Reclamation (USBR) are required by Water Right Decision 1641 (D-1641) to collect phytoplankton and chlorophyll a samples to monitor algal community composition and biomass at select sites in the upper San Francisco Estuary (Estuary). The twenty-four sites range from San Pablo Bay to the inland rivers of the Sacramento-San Joaquin Delta (“the Delta”). These sites represent a variety of aquatic habitats, from narrow, freshwater channels to broad, estuarine bays. The purpose of this article is to describe the results of these monitoring efforts for calendar year 2019.

Phytoplankton are small, free-floating organisms that occur as unicellular, colonial, or filamentous forms (Horne and Goldman, 1994). They primarily serve as an important food source for zooplankton, invertebrates, and certain fish species, although they also have a direct effect on water chemistry. Primary production by phytoplankton, primarily via carbon fixation through photosynthesis, is one of the key processes that influence water quality in the Estuary. Via this process, phytoplankton can affect pH, dissolved oxygen, color, taste, and odor. Under certain conditions, some species (e.g. *Microcystis aeruginosa*) can cause harmful algal blooms (HABs), resulting in animal deaths and human illness (Carmichael, 1981). In freshwater, the cyanobacteria, or blue-green algae (class Cyanophyceae), are responsible for producing toxic blooms, particularly in waters that are polluted with phosphates (van den Hoek et al., 1995). Phytoplankton are also useful for assessing water quality (Gannon and Stemberger 1978); their short life cycles allow them to respond quickly to environmental changes, meaning their standing crop and species composition are indicative of source water characteristics (APHA 2012). However, because of their transient nature, patchiness, and free movement in a lotic environment, the utility of phytoplankton as water quality indicators is limited and should be interpreted in conjunction with other biological and physiochemical data (APHA 2012).

In addition to collecting phytoplankton samples to assess community composition, we use chlorophyll a concentrations as proxies to calculate phytoplankton biomass. Chlorophylls are complex phytopigment molecules found in all photosynthetic organisms. There are several types of chlorophyll, which are distinguished by slight differences in their molecular structures and constituents. These include chlorophyll a, b, c, and d, with a being the principal photosynthetic pigment in the majority of phytoplankton. This makes the chlorophyll a pigment a reliable proxy measurement for phytoplankton biomass. Furthermore, water samples were analyzed for pheophytin a. Pheophytin a is a primary degradation product of chlorophyll a. Its concentration, relative to chlorophyll a, is useful for estimating the general physiological state of phytoplankton populations. When phytoplankton are actively growing, the concentrations of pheophytin a are normally expected to be low in relation to chlorophyll a. Conversely, when the phytoplankton have died and are decaying, levels of pheophytin a are expected to be high in relation to chlorophyll a.

Phytoplankton biomass and the resulting chlorophyll a concentrations in some areas of the Estuary may be influenced by extensive filtration of the water column by the introduced Asian clam, *Potamocorbula amurensis* (Alpine and Cloern 1992). Well-established benthic populations of *P. amurensis* in Suisun and San Pablo bays are thought to have contributed to the low chlorophyll a

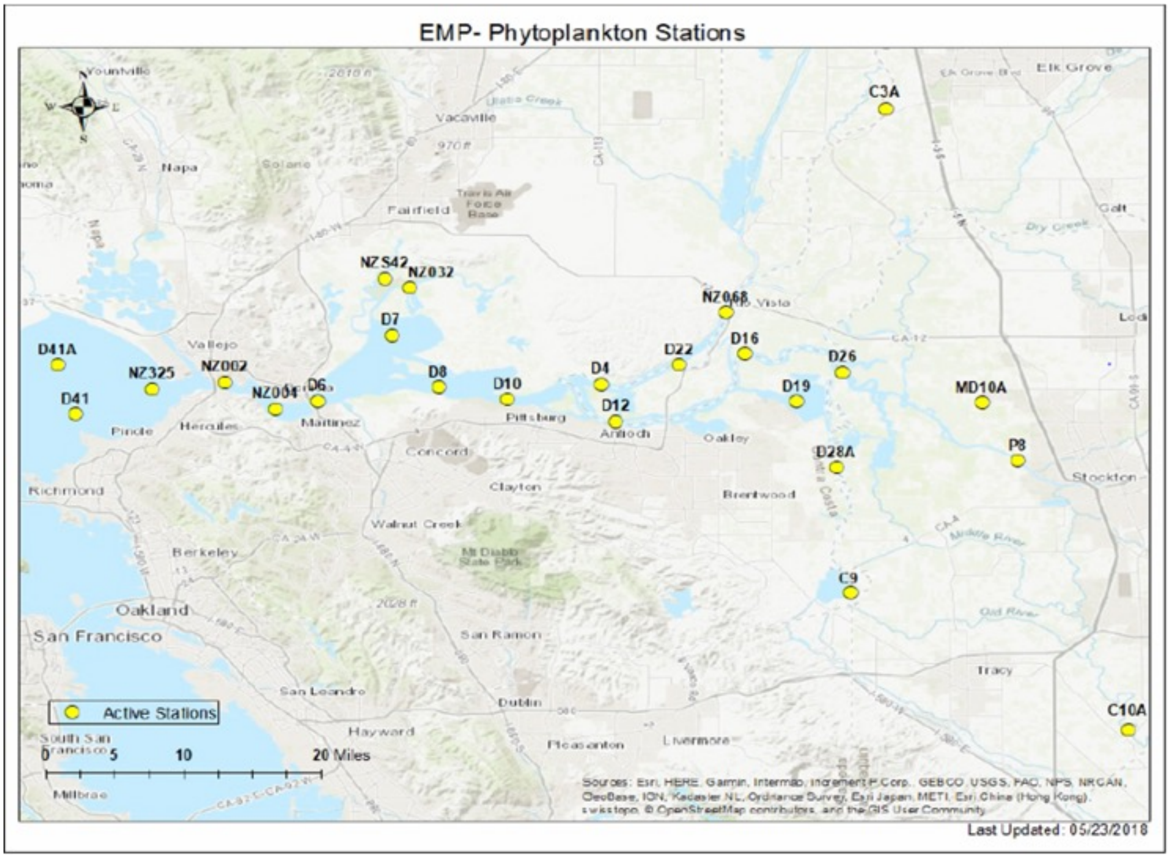

Figure 1. Map of phytoplankton stations sampled by the Environmental Monitoring Program in the upper San Francisco Estuary. Refer to Table 1 to see which stations are assigned to a specific region.

concentrations (and increased water clarity) measured in these westerly bays since the mid-1980s (Alpine and Cloern 1992).

Methods

Phytoplankton

Phytoplankton samples were collected monthly at 24 monitoring sites throughout the upper Estuary, which were grouped into regions based on their geographic location (Figure 1; Table 1). Samples were collected 1 meter below the water's surface using a submersible pump and stored in 50 mL amber glass bottles. 200 µL of Lugol's solution was added to each sample as a stain and preservative. All samples were kept at room temperature and away from direct sunlight until they were analyzed. Phytoplankton identification and enumeration were performed by BSA Environmental, Inc. according to the Utermöhl microscopic

Table 1. Names of the regions sampled by the Environmental Monitoring Program in the upper San Francisco Estuary and which stations are assigned to each region. Refer to Figure 1 for station location in the upper San Francisco Estuary.

Region	Stations
Northern Interior Delta	C3A and NZ068
Southern Interior Delta	C9, C10A, M10A, and P8
Central Delta	D16, D19, D26, and D28A
The Confluence	D4, D10, D12, and D22
Grizzly Bay and Suisun Bay	D7, D8, NZ032, and NZS42
San Pablo Bay	D6, D41, D41A, NZ002, NZ004, and NZ325

method (Utermöhl, 1958) and modified Standard Methods (APHA, 2012). An aliquot was placed into a counting chamber and allowed to settle for a minimum of 12 hours. The aliquot volume, normally 10-20 mL, was adjusted according to the algal population density and the turbidity of the sample. Phytoplankton taxa were enumerated in randomly chosen transects for each settled aliquot. This process was performed at 800x magnification using a Leica DMIL inverted microscope. For each aliquot, a minimum of 400 total algal units were counted, with the dominant taxon accounting for a minimum of 100 algal units. For taxa that were in filaments or colonies, the number of cells per filament or colony was recorded. Raw organism counts were normalized to the sample volume using the following formula:

$$organisms/mL = \frac{CAc}{VA_f F}$$

where C is the organism count, A_c is the area of the cell bottom (mm^2), A_f is the area of each grid field (mm^2), F is the number of fields examined, and V is the settled volume (mL). This simplifies to:

$$organisms/mL = \frac{C}{cV}$$

where $cV=A_c/VA_fF$ and is equal to the counted volume.

The 10 most common genera were determined by summing the normalized organism counts across all stations and months for each genus. For the bar graphs, average organism counts were calculated per month, per region, and normalized to the number of stations. Annual percent composition is calculated by summing algal groups' organisms per mL across all months and stations.

Chlorophyll a and Pheophytin a

Chlorophyll a and pheophytin a samples were collected monthly at 24 monitoring sites throughout the Estuary (Figure 1; Table 1) using a submersible pump positioned 1 meter below the water's surface. The analytes were collected by filtering a known volume of sample water through a glass-fiber filter (1.0 µm pore size) at a pressure of 10 mmHg. If the turbidity was 20 NFU or greater, a 200 mL volume was used, while 500 mL of water was filtered through if the turbidity was less than 20 NFU; this was done to prevent clogging of the filtering apparatus. The filters were immediately frozen and transported to DWR's Bryte Laboratory for analysis using the spectrophotometric procedure, in accordance with the Standard Methods (APHA, 2012). Samples were processed by mechanically grinding the glass-fiber filters and extracting the phytopigments with acetone. Chlorophyll a and pheophytin a pigment absorptions were measured with a spectrophotometer before and after acidification of the sample. Concentrations were calculated according to Standard Method's formula (APHA, 2012). For the bar graphs, average analyte concentrations were calculated per month, per region, and were normalized to the number of stations.

Results

Phytoplankton Identification

All organisms collected in 2019 fell into these ten algal groups:

- Pennate diatoms
- Centric diatoms
- Chrysophytes
- Ciliates
- Cyanobacteria
- Cryptophytes
- Dinoflagellates
- Euglenoids
- Haptophytes
- Green Algae

The 10 most common genera collected in 2019 were, in order:

- *Eucapsis* (cyanobacterium)

- *Chlorella* (green alga)
- *Cyclotella* (centric diatom)
- *Chroococcus* (cyanobacterium)
- *Nitzschia* (pennate diatom)
- *Plagioselmis* (cryptophyte flagellate)
- *Coccomyxa* (green alga)
- *Aulacoseira* (centric diatom)
- *Skeletonema* (centric diatom)
- *Monoraphidium* (green alga)

Of the ten groups identified, cyanobacteria constituted the vast majority (98.2%) of the organisms collected (Figure 2).

Pigment Concentrations

Some stations showed seasonal patterns in chlorophyll a concentration, while others did not. Most maxima occurred in spring and summer, while minima occurred in fall or winter. Monthly chlorophyll a concentrations throughout much of the estuary were relatively low. Of the 288 samples taken in 2019, 98.3% (283 samples) had chlorophyll a levels below 10 µg/L. Chlorophyll a levels below 10 µg/L are considered limiting for zooplankton growth (Müller-Solger et al., 2002). Of the 5 samples with chlorophyll a concentrations equal to or above 10 µg/L, two were at C10A (July and August), two were at NZ032 (August and November), and one was at P8 (September).

The mean chlorophyll a concentration for all samples in 2019 was 2.26 µg/L; the median value was 1.67 µg/L. Both values were lower than their 2018 equivalents (mean = 3.51 µg/L, median = 2.12 µg/L). The maximum chlorophyll a concentration in 2019 was 38.10 µg/L, recorded in July at C10A. This is much lower than the 2018 value (71.87 µg/L). The minimum for 2019 chlorophyll a concentration recorded was 0.50 µg/L, recorded in June at D16, similar to the 2018 value (0.55 µg/L).

The mean pheophytin a concentration for all samples in 2019 was 1.41 µg/L, nearly identical to the 2018 value (1.40 µg/L), and the median value was 1.02 µg/L, which was slightly higher than the 2018 value (0.95 µg/L). The maximum pheophytin a concentration was 13.55 µg/L, recorded at D19 in February, compared to 15.40 µg/L in 2018. The minimum pheophytin a concentration was 0.50 µg/L, which is equivalent to the reporting limit and identical to the 2018 minimum; this was observed at C3A in March and D6 in August. Several sites

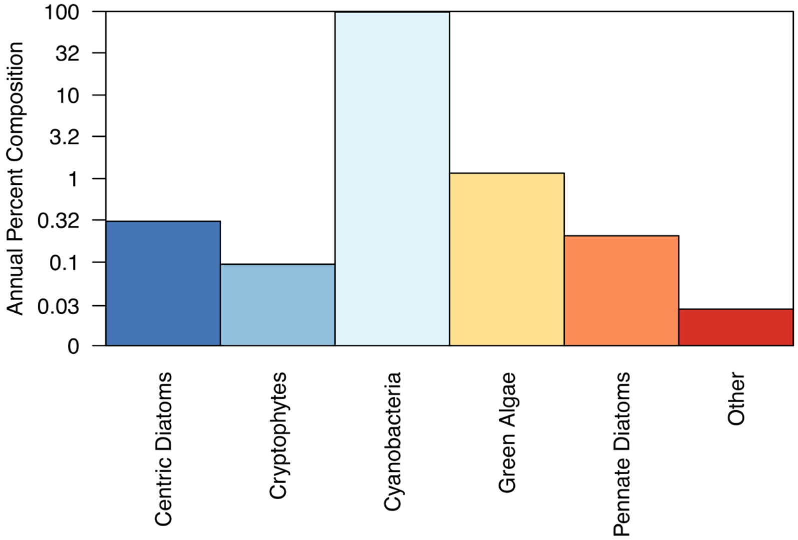

Figure 2. Percent phytoplankton composition by algal group collected in 2019 in the upper San Francisco Estuary at all stations in all months ("other" category is chrysophytes, ciliates, dinoflagellates, euglenoids, and haptophytes). Percent composition is calculated by summing algal groups across all stations and months. Note the $\log_{10}$ scale of the y-axis.

had pheophytin a levels below the reporting limit, primarily in the fall/winter.

Northern Interior Delta

Chlorophyll a average concentrations were higher in early spring and mid-summer, showing a slight seasonal pattern (Figure 3a). The highest concentration was recorded at C3A in April (3.39 µg/L) and the lowest was recorded at NZ068 in July (0.61 µg/L). The mean and median values were 1.54 µg/L and 1.22 µg/L, respectively.

Pheophytin a average concentrations were highest in the winter and late summer; values were lower compared to chlorophyll a (Figure 3a). The maximum (2.29 µg/L) was recorded at NZ068 in January and the minimum (0.50 µg/L) was recorded at C3A in March, although in June concentrations were below the detection limit. The mean and median were 1.05 µg/L and 0.94 µg/L, respectively.

Phytoplankton average concentrations were highest in February-April, with cyanobacteria dominating throughout the year (Figure 4a; “other” are chrysophytes, cryptophytes, and dinoflagellates). Green algae concentrations were relatively high in January through April, and again in August.

Southern Interior Delta

Chlorophyll a average concentrations were highest in the summer and early fall (Figure 3b). The maximum was recorded at C10A in July (38.10 µg/L); the minimum was at MD10A in January (0.62 µg/L). The mean and median were 3.76 µg/L and 2.32 µg/L, respectively.

Pheophytin a average concentrations were fairly constant throughout the year, with a slight spike in the early fall (Figure 3b). The maximum pheophytin a value was recorded at C10A in July (7.53 µg/L); the minimum occurred at P8 in November (0.53 µg/L). The mean and median values were 1.88 µg/L and 1.24 µg/L, respectively.

Phytoplankton average concentrations were highest in late winter and mid-summer, with the highest concentrations occurring in July (Figure 4b; “other” are chrysophytes, ciliates, dinoflagellates, euglenoids, and haptophytes). There was a peak of cyanobacteria in February and a peak of green algae in July.

Central Delta

Chlorophyll a average concentrations were low all year, below 4 µg/L (Figure 3c). The highest chlorophyll a concentration for this region at occurred at D19 in February (3.55 µg/L); the minimum occurred at D16 in June (0.65 µg/L). The mean and median values were 1.25 µg/L and 1.18 µg/L, respectively.

Pheophytin a average concentrations were relatively consistent throughout the year excluding two large spikes in February and December (Figure 3c); the spike in February was the maximum for the year (13.55 µg/L at D19). The minimum was 0.54 µg/L, and was recorded at both D16 in November and D28A in June. The mean and median values were 1.38 µg/L and 0.84 µg/L, respectively.

Phytoplankton average concentrations were high throughout the year, dominated by cyanobacteria and green algae (Figure 4c; “other” are chrysophytes and cryptophytes).

Confluence

Chlorophyll a average concentrations were highest during the late-spring and summer, showing a seasonal pattern (Figure 3d). The highest concentration occurred at D10 in May (4.19 µg/L); the minimum was recorded at D10 in December (0.67 µg/L). The mean and median values were 1.96 µg/L and 1.88 µg/L, respectively.

Pheophytin a average concentrations fluctuated throughout the year, being higher in winter and fall. The maximum concentration was recorded at D10 in August (6.32 µg/L) and the minimum at D10 in November (0.64 µg/L) (Figure 3d). The mean and median for this region were 1.39 µg/L and 1.17 µg/L, respectively.

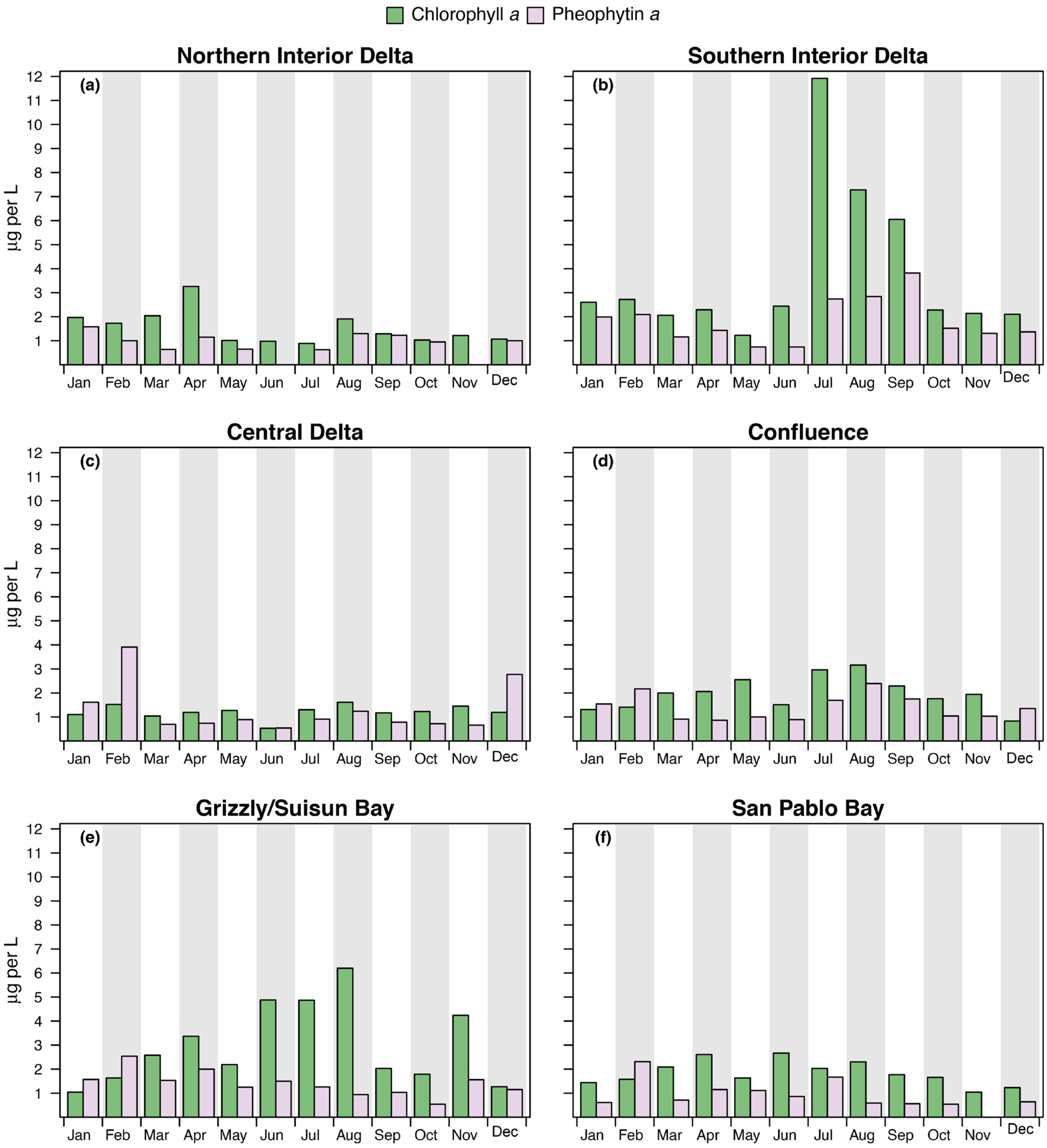

Figure 3. Average chlorophyll a and pheophytin a concentrations in micrograms per liter collected in 2019 in the upper San Francisco Estuary for (a) the Northern Interior Delta, (b) the Southern Interior Delta, (c) the Central Delta, (d) the Confluence, (e) Grizzly and Suisun Bays, and (f) San Pablo Bay. Refer to Figure 1 for station location and Table 1 for which stations are assigned to a specific region. Pheophytin a was below the detection limit in June and November in the Northern Interior Delta, and in November in San Pablo Bay.

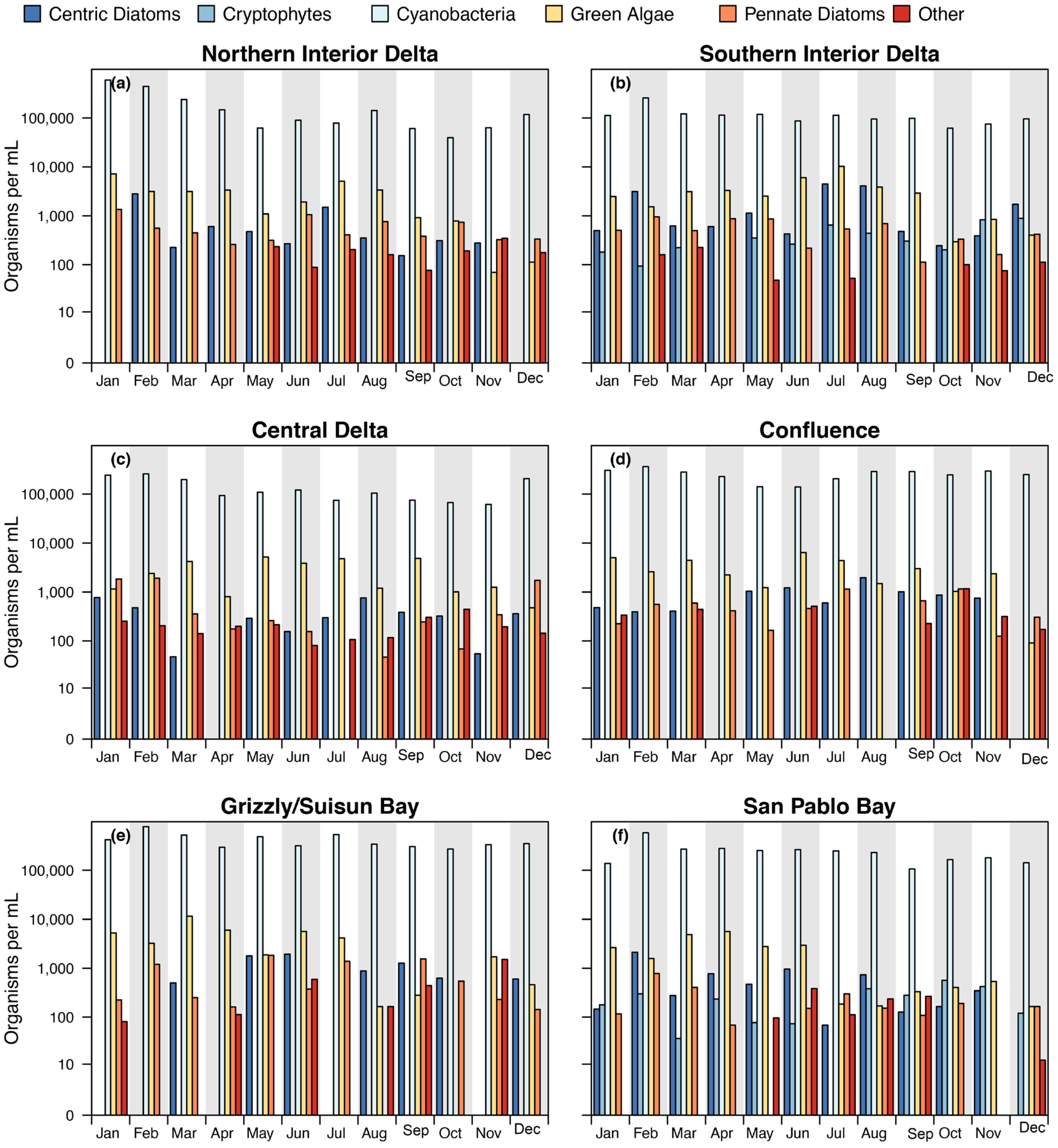

Figure 4. Average organism density in natural units (cells, colonies, or filaments) per milliliter collected in 2019 in the upper San Francisco Estuary in (a) the Northern Interior Delta ("other" category is chrysophytes, cryptophytes, and dinoflagellates); (b) the Southern Interior Delta ("other" category is chrysophytes, ciliates, dinoflagellates, euglenoids, and haptophytes); (c) the Central Delta ("other" category is chrysophytes and cryptophytes); (d) the Confluence ("other" category is cryptophytes and haptophytes); (e) Grizzly and Suisun Bays ("other" category is chrysophytes, cryptophytes, euglenoids, and haptophytes); and (f) San Pablo Bay ("other" category is chrysophytes, dinoflagellates, euglenoids, and haptophytes). Refer to Figure 1 for station location and Table 1 for which stations are assigned to a specific region.

Phytoplankton average concentrations were relatively consistent throughout the year, dominated by cyanobacteria and green algae (Figure 4d; “other” are cryptophytes and haptophytes).

Grizzly Bay and Suisun Bay

Chlorophyll a average concentrations in this region showed a slight seasonal pattern, with higher values in the spring and summer, excluding a fall peak in November (Figure 3e). The maximum was 12.70 µg/L, recorded in August at NZ032; the minimum was recorded at D8 in December (0.65 µg/L). The mean and median were 1.96 µg/L and 1.88 µg/L, respectively.

Pheophytin a average concentrations were relatively low all year, below 4 µg/L (Figure 3e). The maximum (3.56 µg/L) and minimum (0.51 µg/L) concentrations were both recorded at NZS42 in February and October, respectively. The mean and median were 1.45 µg/L and 1.23 µg/L, respectively.

Phytoplankton average concentrations were higher in late winter and early spring, and lower the rest of the year (Figure 4e; “other” are chrysophytes, cryptophytes, euglenoids and haptophytes). Cyanobacteria was the dominate algal group throughout the year, and green algae concentrations spiked in January-July.

San Pablo Bay

Chlorophyll a average concentrations were relatively consistent throughout the year (Figure 3f). The maximum value for the region was recorded at D41 in April (4.46 µg/L); the minimum concentration was recorded at NZ004 in November (0.58 µg/L). The mean and median were 1.84 µg/L and 1.72 µg/L, respectively.

Pheophytin a average concentrations had peaks in Februray and July, but overall values were low, below 4 µg/L (Figure 3f). The maximum was recorded at D41A in February (3.11 µg/L) and the minimum at D6 in August (0.50 µg/L), although November’s concentrations were below the reporting limit. The mean and median were 1.06 µg/L and 0.72 µg/L, respectively.

Phytoplankton average concentrations were highest in the first half of the year (Figure 4f; “other” are chrysophytes, dinoflagellates, euglenoids, and haptophytes). Green algae and cyanobacteria were the dominant taxa.

Conclusions

Some regions showed seasonal patterns in chlorophyll a and pheophytin a concentrations, while others did not. Most maxima occurred in spring and summer, while minima occurred in fall or winter. Some pheophytin a concentrations were below the detection limit. All regions were dominated by cyanobacteria and green algae, with other algal groups making smaller contributions to the phytoplankton community.

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END MATTER

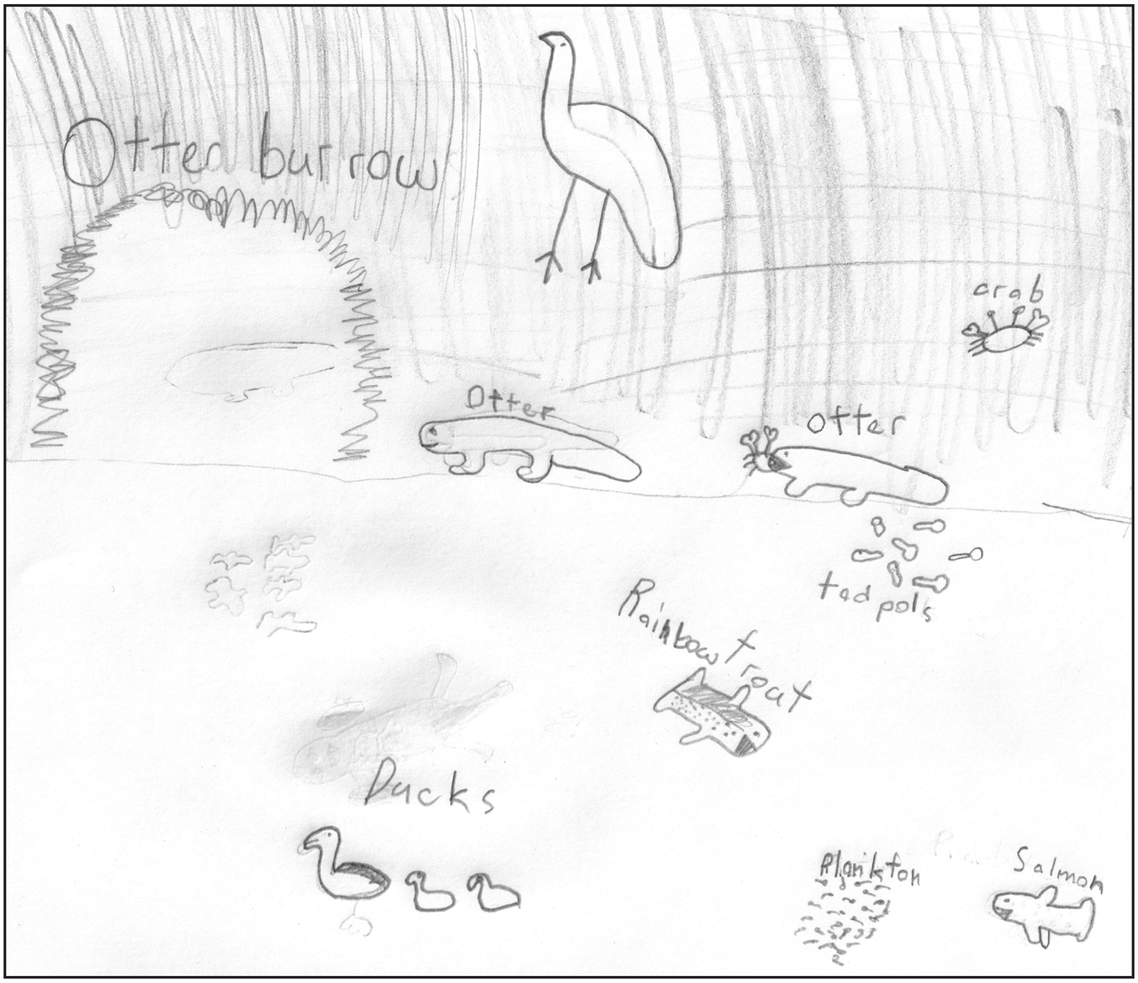
A Note From the Editor

Jereme W. Gaeta (IEP & CDFW)

We all too easily forget what initially inspired us to pursue careers in or associated with natural resources as working adults. Reflecting on the times I snorkeled in La Jolla Cove as a child, for instance, is far from my mind when I find my world condensed to a blinking cursor as a deadline looms. Yet, all of us share similar magical moments of wonder and awe that come from experiencing the natural world around us, and, for many of us, these are the very moments that initially motivated us to study, conserve, and effectively manage the natural resources of the San Francisco Estuary.

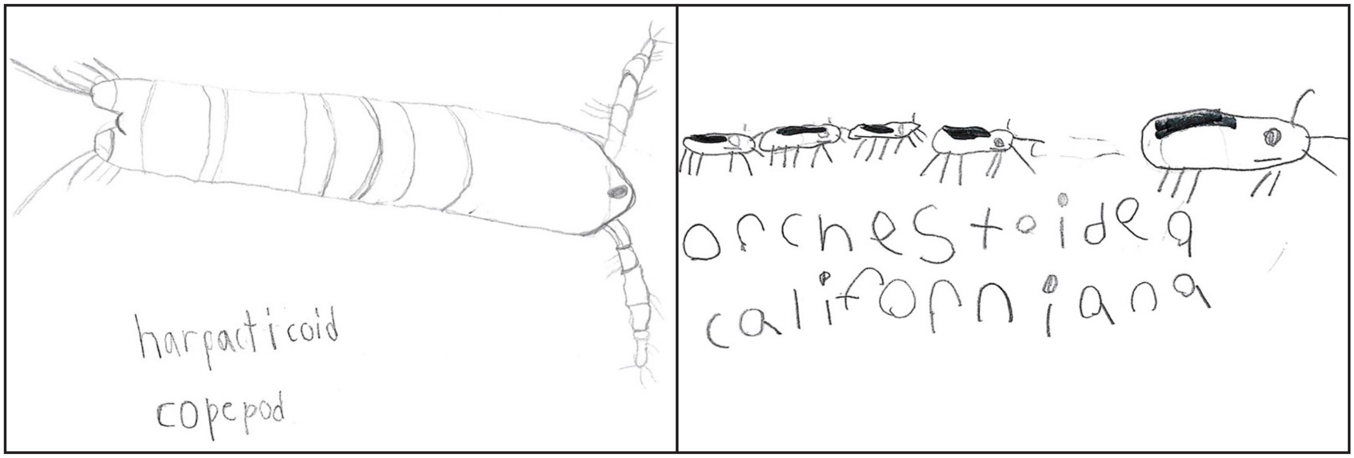
The spark of passion and curiosity that drew me to my career is now most often rekindled when I get to experience nature through the eyes of my nephew. Perhaps my favorite, albeit very loud, reminder is when I hear my nephew scream "***FISH ON!!!***" even when his catch is a mere 3-inch bluegill.

I hope you take the time to enjoy the following art by the children of IEP. May it serve as a reminder of our shared human experience and inspire us as we strive to understand and protect the San Francisco Estuary and the peoples dependent upon its natural resources.



Charlie's response to Stacy Sherman's (Environmental Program Manager at CDFW) request for his "conceptual model" of a marsh. Charlie, now 15, was 8 years old at the time of this drawing. Note the interesting crab-otter predator-prey dynamics.

Lauren's abstract landscape with water bodies. Painted with oil on glass at age 8, now 10 years old. Daughter of Jeff Holt (Senior Environmental Scientist - Specialist at IEP & CDFW).



COVID-19 isolation art projects by Matthew (age 7; left) and William (age 5; right), sons of Steve Slater (Senior Environmental Scientist - Supervisor at CDFW). (Left) pencil drawing of benthic harpacticoid copepod. (Right) pencil and pen drawing of California beach hoppers AKA long-horned beach hoppers (*Orchestoidea californiana*), a species that emerges from intertidal sand burrows to nocturnally feed on decaying seaweed.

Interagency Ecological Program for the San Francisco Estuary

IEP NEWSLETTER

The Interagency Ecological Program for the San Francisco Estuary
is a cooperative effort of the following agencies:

California Department of Water Resources
State Water Resources Control Board
U.S. Bureau of Reclamation
U.S. Army Corps of Engineers

California Department of Fish and Wildlife
U.S. Fish and Wildlife Service
U.S. Geological Survey
U.S. Environmental Protection Agency
National Marine Fisheries Service

USFWS • SWRCB • CDFW • USGS • NMFS • USACE • USEPA • DWR • USBR

Interagency
Ecological Program

COOPERATIVE ECOLOGICAL
INVESTIGATIONS SINCE 1970

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